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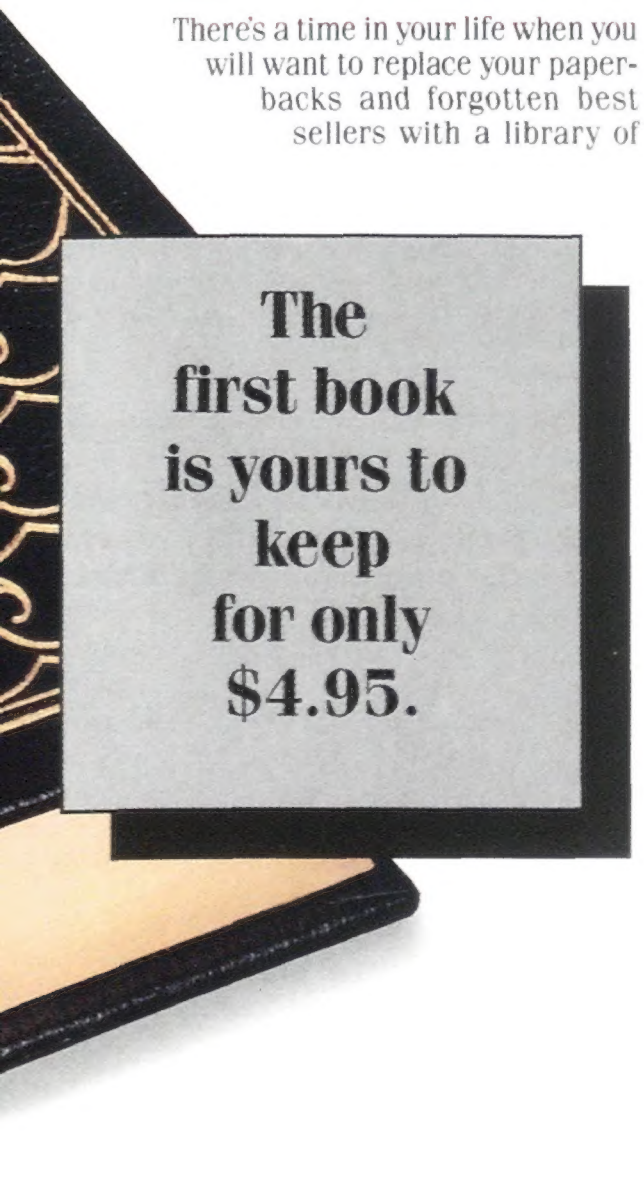

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December 1991/January 1992
Volume 6, Number 5

AIR&SPACE
Smithsonian

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Cover:
Pat Rawlings painted this vision of a 21st century moonbase.

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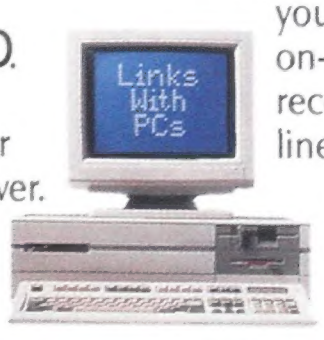

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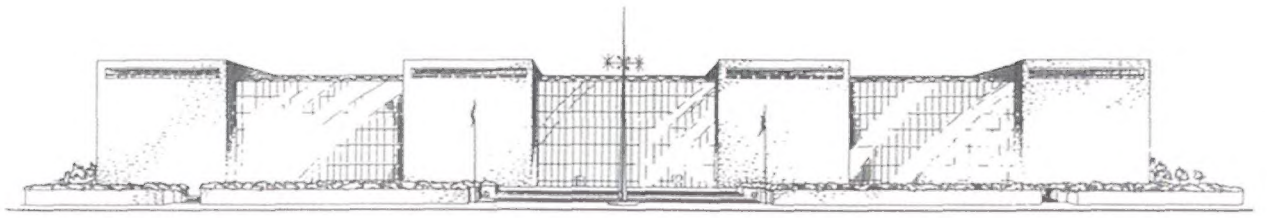

Second-Guessing the Future

I had dinner recently with two friends, Steve and Jim, and we began swapping predictions about space exploration.

I said that if a number of challenges could be overcome, we'd probably succeed in going to Mars and would then try hard to colonize it. These challenges include finding the means for travelers to weather the long journey, such as optimal shielding against cosmic ray irradiation and compensation for the long-term effects of weightlessness on the human body. For colonization, we'd need to study whether the Martian atmosphere and climate can be sufficiently altered to make that planet hospitable for humans and a larger biosphere.

Steve was considerably less brash in his prediction. He foresaw that the United States would have to budget huge expenditures over decades to even prepare for such a mission. With Congress appropriating money one year at a time, such a paced venture could be stopped in its tracks in any year.

Jim pitched in more optimistically. He noted that some of the medieval cathedrals had taken over a century to build. Humans, he argued, do have patience for sustained efforts involving successive generations.

The history of democratically elected governments is not yet long enough to answer such questions, but Jim's remark made me wonder whether the medieval long-term ventures were simply a reflection of more doctrinaire epochs and authoritarian regimes than we find in modern times. In the 12th and 13th centuries, church and royalty could enforce their will for decades without letup, whether a project was popular or not. A democratically elected government cannot implement such draconian measures without getting voted out of office. Steve wondered aloud whether the pyramids in Egypt could ever have been built in a democracy.

Such musings can be turned on their head, and Jim recalled that a Committee on Civil Aviation, set up by Herbert Hoover in 1925, when he was Secretary of Commerce, had failed to foresee anything like the explosive expansion of aviation. The committee members were roughly correct in their forecasts on the short-range applications of aviation, but they failed to appreciate the enormous promise of commercial air travel. Space efforts or the advent of nuclear power would, of course, have been considered topics of science fiction at the time.

Predictions tend to rely on extrapolations based on technology that is well in hand. Most often we are unprepared to accept a totally new perspective—a paradigm shift, in the language of sociology. We cannot twist our thinking around sufficiently to imagine the wide-sweeping impact of a totally new invention, nor the secondary ramifications of its most immediate applications. In the context of space travel, our predictions are likely to fail badly if we leave nuclear fusion out of the picture. Compact fusion reactors could provide virtually unlimited quantities of power at reasonable cost, as might economically efficient solar electrical power plants.

Ready travel to Mars may seem quite unlikely, given nothing beyond present-day chemically powered rockets. But a new, virtually boundless source of energy would almost certainly change all that. The main obstacle to extensive travel to space, after all, is the lack of a cheap source of power.

Long-term predictions are difficult, because most of us fail to appreciate the need for a paradigm shift. That myopia results in consistent underestimates of the possible and even the probable.

It's reassuring to think that ultimately we will accomplish much more than even our brashest prophecies would lead us to believe. Comforting as that may be, it would be even better if we could tell just which new technologies will turn the miracle, and where that future will take us in the exploration of space.

—Martin Harwit is the director of the National Air and Space Museum.

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Letters

Warbird Woes

"Wings of the Great War" by Jeffrey L. Ethell (October/November 1991) was superb. I have had an interest in these airplanes ever since I built models of them out of balsa wood and tissue, with power supplied by rubber bands. Like Ethell's, mine were also unstable in flight.

J. William Battis
La Verne, California

You had a wonderful opportunity to fly and competently report on not just one but four vintage fighters and you bombed. I went through flight training at Pensacola in 1951 and now, at age 62, I would give my eyeteeth to strap one on. I have read the story three times and my feelings range from disappointment and anger to disbelief. Maybe those were the days of iron men and wooden props.

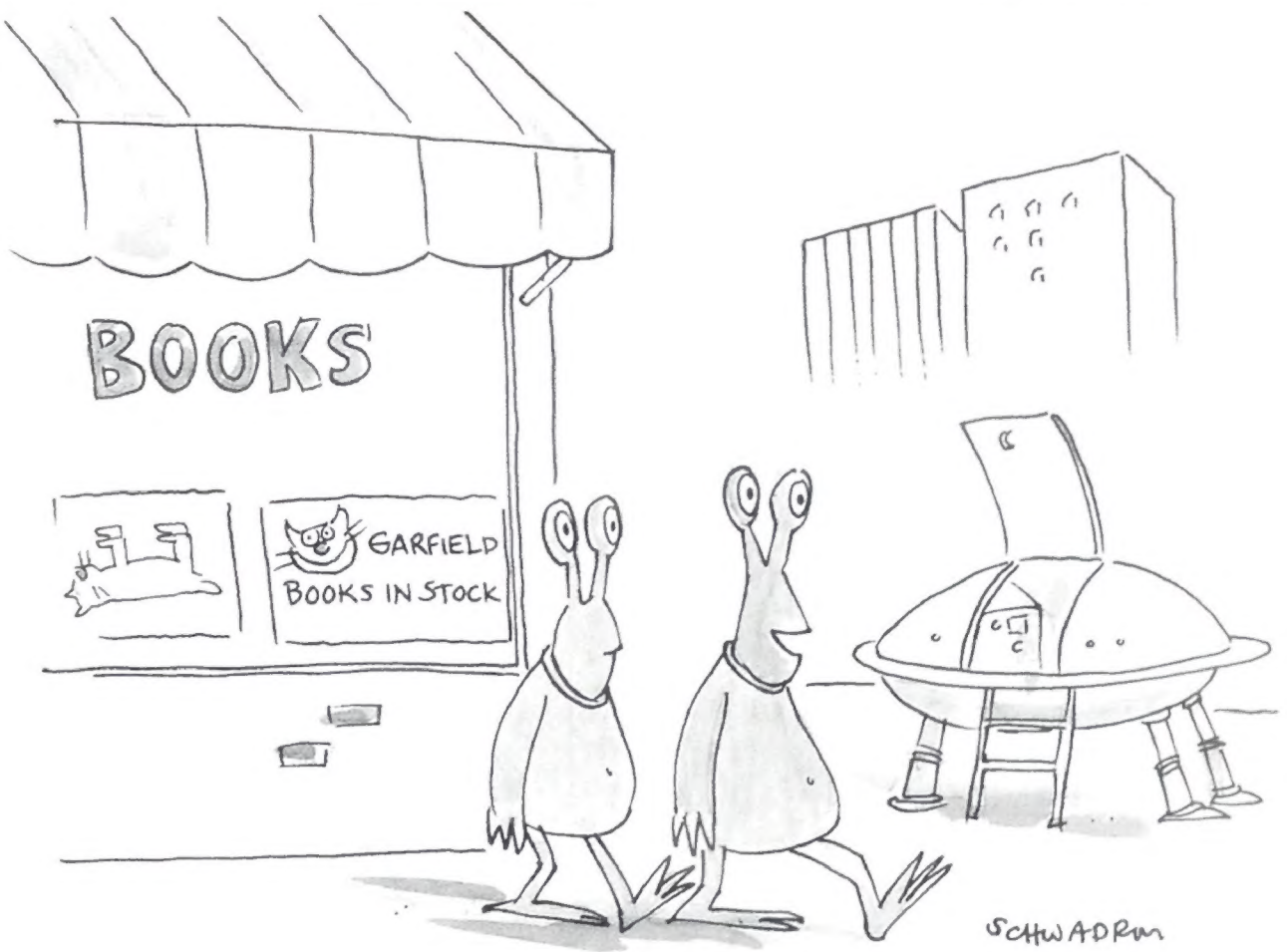
Donald L. Newell
Elberta, Alabama

Jeffrey L. Ethell replies: Contemporary pilots don't realize how difficult the flying environment was. Though I may have come off as aviation's ultimate wimp, all one has to do is read the biographies of the Great War pilots to find out that my reactions were only a thimbleful of what these men experienced.

They All Cried

I am a 65-year-old retired Air Force lieutenant colonel. I am also white-haired, white-bearded, tough, obstinate, and salty. I graduated from pilot school in 1952 and have since lost a good number of my classmates. "Taps for G102" by Steven L. Thompson (Groundling's Notebook, October/November 1991) is the most moving magazine article I have ever read. I cried!

James A. McMillan
Maysville, Kentucky



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The tears have just stopped flowing after I read Thompson's tribute to his father. I wasn't really an Air Force brat (my father left the Air Force before I was born). And he wasn't a pilot, he was a "gun plumber" on P-51s. Many years into his civilian life, my father finally achieved his dream of learning to fly, passing on his love of aircraft to me. Several years ago I took him to see the Confederate Air Force's B-29. As that old airplane lumbered over the airport on a low pass, my father straightened up and held a crisp salute, something I'd never seen him do. There was a moistness in his eyes that said it all, a salute to all of those men and machines that he had known and loved in another time and place—men like Thompson's father.

Eric A. Overby
Dallas, Texas

Flying Is Not for Everyone

"Integrated Transportation Systems" by Martin Harwit (Viewport, October/November 1991) failed to note the most expeditious means of travel from Washington, D.C., to Lake Cayuga, New York: the general aviation airplane. Harwit's failure to even mention the general aviation option (in an aviation magazine, no less) says a lot about its state in our country. Very disheartening.

David Heal
Santa Rosa, California

Martin Harwit replies: As pilots, you and I, of course, could fly from Washington, D.C., to Ithaca, New York. But this is not an option open to most people. If everyone in America had his own airplane, I suspect East Coast skies would be totally clogged.

When I Knew James Salter

"A Single Daring Act" (October/November 1991) brings back wonderful memories of author James Salter and the legendary exploits of the guys in "Dog Flight," the 335th Fighter Squadron of the Fourth Fighter Group. While all the events Salter recounts were going on, I lived in the adjoining room with "Charlie Flight" and spent many hours airborne on the same missions with the squadron. Salter, a fine fighter pilot and excellent leader, had the unique ability to transform the tedium of combat—when we weren't in the air—into a lot of fun. His brilliance and sophisticated sense of humor were key in melding the diverse personalities within Dog Flight into a proud and effective fighting unit.

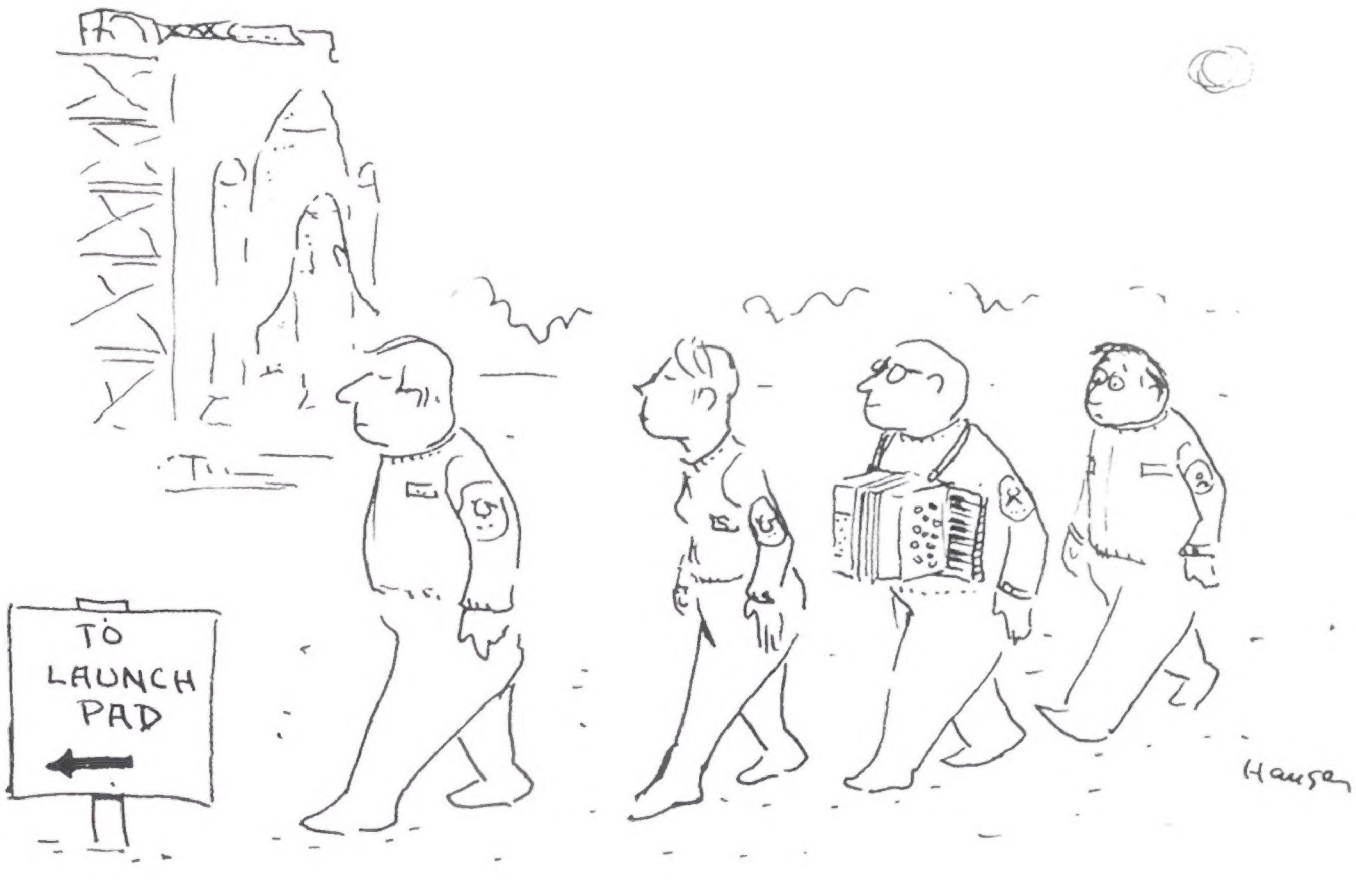
Salter's flight commander, Phil Colman, was seldom if ever called "Phil." Colman was assigned the nickname "Casey" the moment he returned to his quarters after serving as engineer, fireman, and conductor of that Sabre he skillfully landed on the railroad track leading to the salvage yard. The name Casey came from an old ballad about a locomotive out of control, with Casey Jones at the throttle.

Salter was an accomplished artist who liked to steal around late at night painting caricatures on the walls of various flight rooms and other sensitive public areas. He devised what later became *the* shoulder patch insignia of Dog Flight. The paintings, entitled "Mach Rider in the Sky," depicted a small Sabre with a very large Casey head smoking a huge cigar and wearing a flamenco dancer's hat with a wide brim. Every two inches or so would hang a black tassel. As the other two squadrons swallowed the indignation of being upstaged, they dispatched their own artists to paint Skyrockets and pissed-off Pigeons in the vicinity of the Mach Rider. To one-up all these additions to his frescoes, Salter would simply lengthen the brim of Casey's hat, adding sufficient tassels, until the brim actually encircled all four walls of the room, engulfing the offenders' meager and amateurish additions.

The exciting days at Dog Flight began to subside in late summer 1952, when Salter was promoted to command Baker Flight. By this time, Bob Ronca, Coy Austin, and Al Smiley had ratcheted through their remaining missions and Casey was back in Savannah, Georgia. Aces Jim Kasler and Jim Low were whisked back to the training command to help motivate future MiG killers. I think that this Dog Flight destroyed at least 25 MiGs in three or four months.

By early fall, when there were no more walls to paint, Salter had flown his 100th and was rotated Stateside. Two months later I joined the 75th Fighter Squadron on Long Island, and who was the first to greet me? James Salter. The next two years are another story.

Lieutenant Colonel Martin J. Bambrick
U.S. Air Force (ret.)
Hagerstown, Maryland



We know of poetic license, and when writing fiction the author may need to romanticize, but in real life it's better to stick to the facts. Now for some of the rest of the story James Salter tells in "A Single Daring Act": I have known Phil Colman since 1949, when I checked him out in the F-80C. On that first flight, Phil demonstrated more knowledge about his aircraft than most of our squadron pilots with over 100 jet fighter hours (in those days, that was a bunch).

Now let me see if I can set the record straight. (This letter was written with Phil Colman's approval, as I am now his lawyer.) First, Phil did not, as stated in the article, land at the Fourth Fighter Base from a supply line mission in an F-84. He never flew the F-84 in combat. He hitched a ride from Misawa Air Base in Japan to K-8 in an SA-16. He did not throw his flight records in the sea; they were lost while we were still at George Air Force Base in Victorville, California. Colman

was not on his first flight when he landed at the gate to the salvage yard. He knew how to manage his fuel tanks, and his fuel gauge was reading 60 gallons when he flamed out in the traffic pattern. The accident was ruled material failure. The conversation with the squadron commander, in which Phil is quoted as saying "I f——d up," never took place. Salter must have quoted someone else, as he was not even on the base at the time of the accident; he arrived about two months later. One of the good reasons Phil carried binoculars was that if he could identify aircraft as F-86s, he would not drop his external fuel tanks. As for his being magnanimous, Phil was that. He would allow his wingmen the opportunity to fire at MiGs, and as a matter of fact he had two aces in his flight. Had he taken all the opportunities himself, Phil would have been a double or triple ace.

As for the accident, many years later I asked for and received Phil's medical records from the Air Force. Phil had sustained a 30 percent compression fracture of the first lumbar vertebra and had, in fact, flown 86 combat missions in the F-86 with a broken back.

Phil wore a regulation helmet, and as for "cigar-stained" teeth, he brushes them. I have seen him do it and he still has all of them. Phil is now a retired colonel and a retired Volkswagen dealer who lives in Augusta, Georgia.

Colonel Phillips D. Hamilton
U.S. Air Force (ret.)
Statesboro, Georgia

James Salter replies: Philip Colman's arrival and early days in Korea are not something I saw but rather heard about, as I have said, from Colman and others. If I have gotten a detail or two down inexactly, or drawn them from more colorful versions, I stand corrected. Colman is brilliant and inimitable, and his story, for me, is also.

Correction

In "Fast Forward on Venus" (October/November 1991), the caption on page 56 misidentified the Galileo spacecraft as the Magellan.

We welcome comments from readers. Letters must be signed and include a daytime telephone number. Letters may be edited. Write to Air & Space/Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024.* Air & Space *is not responsible for the return of unsolicited photographs or other materials.*

The Faces That Launched a Thousand Ships

A dozen of the U.S. space program's most eligible bachelors have loaned their names—and bodies—to a 1992 calendar that hit the market last October. "Strictly young, single, and sexy," says shuttle software analyst Cheryl Farmer of the first-time models she and three co-workers chose to feature as "The Men of Kennedy Space Center."

The calendar aims to raise money for charity, but the models aim to change public perception of engineers and scientists. "This is going to verify that not all engineers are pencil-necked geeks," says Jim Gentile, a Rockwell International engineer who posed in skintight zebra-striped trunks. "Athletic, friendly, honest!" reads the blurb on the West Point graduate and ex-collegiate football star.

What started quietly as a fundraising project for adult literacy in Brevard County, Florida, has blossomed into a global marketing project for Flash Productions, the home business Farmer founded to produce and sell the calendar. "It started out just being an inside source for eligible men," she says, but "our telephones are ringing like crazy." Orders were arriving from Canada and the Philippines as the news spread last fall. Almost 5,000 copies were ordered before the calendar was printed.

All the models work for NASA or its contractors at Kennedy Space Center. They're all clothed—in everything from chaps to tuxedos—and posed in leisurely settings. Gentile's bare-chested pose is the most risqué of the 12. "We wanted to give a good peek at the guys and their personalities, but we wanted the image portrayed to be as tasteful as possible," says photographer Valerie Wardell. "People think we're all crew-cut squares wearing ties, and we're out to change that," says NASA's Mike Murazzi, who's shown leaning on his guitar beside a railroad track, shoulder-length brown hair blowing in the wind. "Michael has a hidden talent," says his blurb. "He can wiggle his ears!"

The men kept mum about the voluntary project for several months to forestall teasing from co-workers. Now that the news is out, "they're singing 'Calendar Boy' every time I walk down the hall," says Gentile.

—Beth Dickey

Update

Anyone Missing a 16-Kilo Package?

Mechanics discovered 35 pounds of cocaine aboard a Lockheed L-1011 wide-body airliner in storage at Mojave Airport in California last October (Soundings, August/September 1991). Employees of Aerotest made the find while preparing the ex-Eastern Airlines aircraft, which had been in storage at Mojave for 10 months, for delivery to Delta Airlines.

NOAA's New Weathercock

During the past year strange little stations have sprouted near heartland towns like Blue River, Wisconsin, Medicine Bow, Wyoming, and Tucumcari, New Mexico. Surrounded by a chain-link fence, each features a lattice-like antenna on a supporting frame that sits a few feet off the ground. Within the enclosure and packed with electronic gear is a white shelter that looks like a deluxe toolshed.

Twenty-seven of these automated stations are now scattered around the central United States as part of a $16 million demonstration network that the National Oceanic and Atmospheric Administration hopes will revolutionize the way weather forecasters and aviation route planners obtain vital wind data. Called wind profilers, the upward-looking Doppler radars produce extremely detailed information on wind speed and direction at altitudes from 1,600 feet to 10 miles above ground.

Every six minutes each station yields a

profile of winds in 72 vertical increments, says Russell Chadwick of NOAA's forecast systems lab in Boulder, Colorado. When processed and extrapolated, the data describes wind conditions for nine-mile intervals. The current nationwide grid has only a 50-mile resolution.

Forecasters and route planners now get most of their information on upper-level winds from instrument-bearing balloons released every 12 hours. "Airliners also automatically report en route wind information," says Chadwick. "But that data is pretty much limited to their usual flight paths, from 32,000 to 35,000 feet." That leaves gaps in time and space—gaps that could be liabilities or lost opportunities.

"Jets, or winds of 70 knots or more, move around and are kind of hard to predict," Chadwick says. "The near-continuous amount of detail that comes from the profilers will let commercial and general aviation people plan routes and suggest altitude changes that avoid strong headwinds or take advantage of tailwinds. This could result in substantial fuel savings." Additionally, farmers could benefit from better local forecasts of heavy winds and rain.

The Department of Commerce and the Federal Aviation Administration are funding the demonstration network through 1994. If there are sufficient benefits in fuel savings, more efficient use of airspace, better weather forecasting, and safety, the system could be installed nationwide.

Developed at NOAA's environmental research labs in Boulder and built by Unisys Defense Systems in Great Neck, New York, the wind profilers are somewhat different from the NEXRAD weather radar system currently being tested. "It's the same kind of Doppler signal processing," says Chadwick, "but NEXRAD looks out along the horizon to, for example, detect wind shear. These [profilers] look up." And, he adds, "Because its beams are fixed and finely tuned, as opposed to sweeping a larger area, we're getting returns off turbulent eddies in clear air, even from eddies that are very weak."

So far, the system is performing pretty much as NOAA had envisioned. However, while it was designed to operate unattended and with little maintenance, Chadwick concedes that "we've found a few design flaws that have cut down on the system's predicted reliability. We knew that there's a lot of lightning in the central U.S., but we didn't know it would have such a fondness for profilers."

—Jay Stuller

Update

Humor in Uniform?

Tests of a missile decoy system that will protect ground-bound tactical air control systems will begin in February 1992 ("Electronic War," February/March 1991). According to a news release from the U.S. Air Force's electronic systems division, the decoys confuse incoming anti-radiation missiles "and lure them into a safe impact area...referred to as the 'ARMpit.' "

High Tea

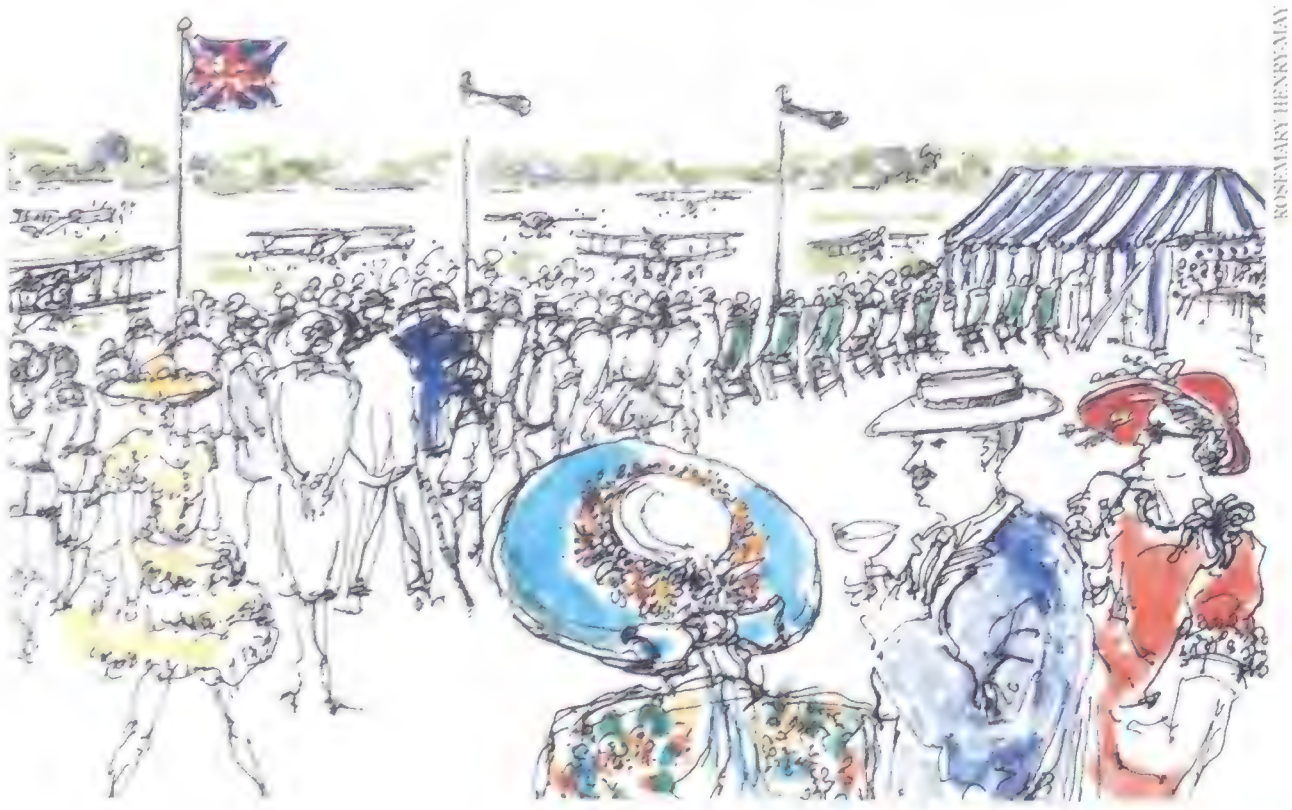
Old Warden Aerodrome hadn't seen anything like it since the days of leather caps and goggles. The airfield, north of London and home to the Shuttleworth Trust collection of classic aircraft, is normally pretty sleepy. But last September 8 it woke up. Overhead, 20 of the Shuttleworth oldies, plus visiting aircraft, all buzzed and roared in a spectacular display of a rebuilt World War I and II armada. And on the ground was a lavish garden party, complete with champagne.

The occasion was a double birthday. The Society of British Aerospace Companies and the Royal Aeronautical Society turned 75 and 125 years old respectively this year, and to commemorate the dual event the societies decided to re-create a typical 1930s garden party, once a popular feature on aviation's social calendar. The event lured some 5,000 flight fanatics, emptying the nearby hamlet of Biggleswade and probably the entire county of Bedfordshire as well. Many turned out with picture hats and parasols. For £35 they received lunch and, later, tea. While the swells dined under a huge flapping tent, a more informal group in bare feet and shorts picnicked on the grass and in cars. By noon the airfield was covered with deck chairs and plaid blankets, which were laden with homemade pies, fried chicken, and bottles of wine. A strolling band, in blazers and boaters and gleaming white shoes, played Dixieland numbers. Those without lunch bought fish and chips and steak-and-kidney pie at stalls. The legendary country airfield smelled like a mix of county fair and gasoline.

"A very grassroots affair" is how the SBAC's Brenda Cowling, head of public affairs, described it. "The alternative [celebration] would have been a £100-a-head dinner at the Savoy in London."

Before the show, guests mingled in the hangars housing the Shuttleworth's permanent exhibits, where antique engines, propellers, and instruments are displayed along with an ornithopter, a Blériot, and a Sopwith Pup. "It's a living museum," says refurbisher Peter Shuttleworth (no relation to the Trust's founders). "The Royal Air Force Museum in Hendon is nice, but their planes never move. It's quite a different thing to see them rolled out here, actually working."

Once the flying started, everyone dragged chairs and blankets to the fence along the runway. Spitfires and



ROSEMARY HENRY-MAY

Hurricanes roared by, 51 years after they had fought the Battle of Britain. The highlight was a flyover of Shuttleworth's de Havilland 88 Comet racer and a D.H. 98 Mosquito bomber. The bright red wooden Comet, which returned to the air in 1987 after 14 years of rebuilding, delighted the camcorder set. But neither aircraft could land at Old Warden, where the two grass strips are a mere 2,300 feet, barring any high-performance aircraft (save a Harrier) from getting in.

Other flyovers included a Royal Aircraft Factory S.E.5a fighter, a 1918 Avro 504K, a Miles Magister, the only Gloster Gladiator (the Royal Air Force's last biplane fighter) still flying, and the silver Percival Gull Six used by Jean Batten in 1935 for the first South Atlantic crossing by a woman. Each got a hero's welcome from the partygoers. The outing, said RAS president Gordon McCoombe, was meant to "bring a touch of nostalgia to a type of event fashionable between the wars." It may just bring the aeronautical garden party back into style.

—Joshua Jampol

At $1,100 a Minute, Time Flies

"It was worth it at twice the price," said S. Harry Robertson. The slightly woozy 56-year-old aerospace executive had just spent $10,000 for a nine-minute ride in a two-seat MiG-29 fighter. He was one of a trio of aficionados who had presented the Soviets with cashier's checks to joyride during the MiG's visit to the Fort Worth, Texas airshow last October. "For years we've been trying to beat these guys," he said. "We were trained to fight them. Now, riding in this plane is a once-in-a-lifetime experience. To strap it on is a rare privilege."

Six months before, the very day he read in an aviation magazine about the opportunity to fly in a MiG, Robertson, who owns a company that manufactures fuel systems for military aircraft, had begun a quest to secure a seat. It paid off for all parties concerned. His ride included a takeoff on afterburner, a loop, several rolls (one with the gear down), a dozen high-G turns, a hammerhead, and two of the famous Soviet tail slides. For the last few years Soviet pilots have been dazzling airshow audiences with this maneuver, in which they climb the aircraft nearly vertically for several hundred feet and then cut the power. For a moment the fighter is suspended straight up; then it slides backward before nosing over into normal flight.

On the second tail slide, Mikoyan test pilot Valeri Menitsky had Robertson take hold of the backseat controls. "It got real quiet," said Robertson. No stranger to the cockpit, the ex-Air Force pilot has flown B-47s, F-100s, and even an F-16. But when it was all over he admitted he was a bit out of condition for this type of mission.

While all this transpired, Robertson's 35-year-old son Dave watched with an envious grin, even though the airline pilot had bought a MiG flight when the Soviets dropped in on Harrisburg, Pennsylvania, during their six-city airshow tour. "He's getting a better flight than I did," said the younger Robertson.

—Byron Harris

BYRON HARRIS

NASA Knockoffs

Not many people, except the resident farmers, know that Greenfield, California, is the Broccoli Capital of the World, says Jim Adamson. Co-owner of SpaceProps, he also wants to tout his town as the Spacesuit Mockup Capital of the World.

NASA

A bona fide shuttle spacesuit weighs 100 pounds and costs about $1.5 million. SpaceProps makes a 35-pound model for $5,000—or $10,000 if you want a Manned Maneuvering Unit attached. Of course, the biggest challenge the creations will face is wear and tear from use in a commercial, a movie, or a museum display.

Adamson was a science writer doing consulting work for U.S. Space Camp in Huntsville, Alabama, in 1984 when he discovered that the campers had no spacesuits. "When Jim came home and said, 'Do you want to make a spacesuit?' I wasn't sure I wanted to attempt it," says Adamson's wife and SpaceProps co-founder Laurel Adamson. "Unlike him I had no idea about space or even what spacesuits looked like." But Laurel, who studied costume design at Brigham Young University, went ahead and laid out their first spacesuit from a pattern they drafted during a visit to the Suit Room at the Marshall Space Flight Center.

Now, some 75 suits later, SpaceProps suits are starring in movies and commercials. "People call NASA or Space Camp and ask them if they have a suit they can borrow," says Jim Adamson. "When NASA stops laughing they refer them to us." Johnson Space Center exhibits manager Louis Parker says he gets three or four requests a week for suits. "SpaceProps is the only one on our list that people can go to and buy mockups," he says. "His are pretty close and they look pretty realistic."

"We go for the appearance," Jim Adamson says. "I'd put them in the 90

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percent [realistic] category. There are some that you really think you could go EVA [extra-vehicular activity] in them."

Some end up in distinctly down-to-Earth scenarios. "The most unusual [request] was for a company that made sausage casings," he recalls. "The ad campaign was designed to show the similarities between their high-tech sausage casing and a spacesuit: both kept out unwanted elements of the environment and sealed in protection."

SpaceProps also did 10 suits for the sci-fi TV movie *Plymouth* and has suits on display at NASA facilities and at museums in Japan, Denmark, and Scotland. And, Jim Adamson adds, "NASA selected our suit to be used by their Spacemobile [aerospace education] Program. That's 32 suits."

SpaceProps also gets occasional inquiries from individuals. But, constructed of $100-a-yard Teflon fabric and retailing at $5,000 plus, "for Halloween it's a little expensive," Adamson says. Then again, $250 will rent you one for a day.

—Bob McCafferty

JORDAN COONRAD

Neil Armstrong, Peter Everest, Fitz Fulton, and Jim Walker reminisced in Lancaster.

Monumental Achievements

"If we build it, they will come." So dreamed the Lancaster, California city council a year ago when they inaugurated the "first and only" Aerospace Walk of Honor along Lancaster Boulevard, 20 miles as the X-15 flies from the Flight T... Center at Edwards Air Force Base in th... Mojave Desert. Every year, the counci... decreed, five six-foot-tall monuments would be erected on downtown sidew... to commemorate the achievements o... test pilots associated with Edwards—...

for each council member to host. There would be fetes and celebrations the likes of which Lancaster had never seen.

So they built it, and they did come. In sequined gowns and black tie, they waltzed across the ballroom at the Best Western Antelope Valley Inn the night before the unveiling of the second set of monuments last September. One by one, the tuxedo-clad honorees—Neil Armstrong, Fitz Fulton, Pete Everest, and representatives for the late Joe Walker and Al Boyd—ascended the stage to a standing ovation while their achievements were read from the program.

Everest, former chief of flight test operations at Edwards, waited with mock impatience as each of the 36 aircraft he tested was read. Then a sterling silver medallion was hung around his neck. He got in a few good-humored digs at his old crony Chuck Yeager, who had been similarly honored the year before. "I've still got a few things over Chuck," he said. "What little he knows I taught him. And I've got more hair."

Combined, the 1991 honorees flew over 62,000 hours in more than 1,430 aircraft. But no one came close to the record of Major General Albert Boyd, who, by the time he retired in 1957, had flown more than 23,000 hours in 723 military aircraft. Boyd was the first commander of the Air Force Flight Test Center at Edwards, established in 1949, and was, Everest told the audience, "a visionary. He was a pilot's pilot. He would never send any of us up in a plane that he wouldn't first go up in himself."

Fitz Fulton's long career included 23 years with the Air Force, 20 years as NASA's chief test pilot, and another three years as chief research pilot for Burt Rutan's Scaled Composites. "I remember Neil Armstrong as a young test pilot with a crew cut," Fulton said after accepting his medal. "He looked like he ought to get ahead, and he did."

Armstrong, who was a test pilot for the National Advisory Committee for Aeronautics and its successor, NASA, from 1955 to 1962, recalled his time in the Antelope Valley with a couple of one-liners. "Snow was welcome," he said, "but not frequent." The perpetually blue skies were, he added, "very desirable for those of us who were never very good at flying on instruments." He spoke highly of his boss at the NACA, Joe Walker, who was killed in 1966 (see Above & Beyond, December 1990/January 1991). "He was my teacher," Armstrong said. "Much that I learned and later achieved I'm sure is due in large measure to Joe's efforts."

"I knew he was special because

everyone said so," said Jim Walker, who accepted the medal on behalf of his father. "But other than that, he was just a regular guy. I didn't know the job was dangerous."

Anyone not inclined to attend the $50-a-plate dinner could catch a replay of the ceremony the next afternoon when the monuments were unveiled. The desert sun beat down on the 300 people gathered in a roped-off area in the middle of the street. As they fanned their faces with programs, the mayor stood up and asked, "Is this great or what?"

At the current rate, in another 10 years the 10-block area of downtown Lancaster will be shoulder to shoulder with monuments honoring 60 pilots. After that, the Aerospace Walk of Honor will be diverted to side streets, lest it become more a tunnel than a walk.

—Elaine de Man

A Moveable Feast

NASA's space shuttle runs on liquid hydrogen and liquid oxygen, but legumes are the fuel of choice for the engineers who launch it. Instead of popping champagne corks or hoisting beer mugs after a successful launch, the Kennedy Space Center team feasts on beans.

"It's become a real tradition. We'd never get away with stopping it now," says Norm Carlson, who started it all with a homemade snack when the first shuttle was launched in 1981.

Carlson, chief of the vehicle processing division at Kennedy, hosted his 42nd post-launch beanfest last September 12. Five

NASA

hundred people gobbled up 55 gallons of beans before the shuttle *Discovery* had been up for an hour. The shuttle took off at 7:11 p.m., but four employees had started cooking around noon in the "bean rooms" on the fourth floor. "Once we know we have a good launch, we spread the cookers all the way down the hall," says Carlson.

It's not unusual to find astronauts and NASA heads in the bean line after a launch, and servings are hand-delivered to Mission Control via NASA jets bound for Houston. If a launch is scrubbed, the beans are frozen for the second or third try; if the third one fails the beans are eaten anyway, in a less festive atmosphere, or are thrown out.

The recipe for a 5-gallon batch calls for 5 to 6 pounds of Great Northern beans, 3 pounds of onions, 2 celery stalks, 10 pounds of ham, lemon pepper, and liquid smoke. "The only ingredient Norm doesn't have in there is the one that will make my hair grow," says Bob Sieck, the balding launch director.

—Beth Dickey

Update

Sparring Over Mars

A former member of the Viking project who wants to update project equipment for a 1996 Soviet flight to Mars says he is being given short shrift by NASA ("The Case for Life on Mars," February/March 1991). Gilbert Levin says the Soviet Space Research Institute has offered to develop and build similar instrumentation to search for life on Mars but says NASA has been "extremely negative" about supplying the $1 million needed for travel costs, data analysis, and updated engineering drawings. NASA officials say Levin has not provided enough information for the agency to make a decision on funding.

Alaska Airlines' Airsickness

Frequent fliers rated Alaska Airlines as having the best air quality among the nation's air carriers in a recent *Consumer Reports* poll, but union officials aren't so confident about the ventilation on some company aircraft since a mysterious

Satellite photos taken in 1979 and 1991 provide a lofty view of the increase in urban sprawl over 12 years. Taken by U.S. Air Force Defense Meteorological satellites in polar orbits 450 miles up, these mosaics, which resolve features down to two miles, were pieced together by retired Air Force satellite meteorologist Hank Brandli.

HANK BRANDLI

illness began felling flight attendants. In the summer of 1989 the first of 235 crew members began complaining of symptoms ranging from dizziness and trembling to neurological problems. No apparent cause has been found.

Nor can Alaska Airlines explain why the illness is disappearing as quickly as it appeared or why it has hit only a small percentage of the 64-airplane fleet. Despite a year-long investigation, even the National Institute for Occupational Safety and Health is baffled. "Nothing about this whole thing makes sense," says NIOSH industrial hygienist Aaron Sussell. "If something were wrong with the planes, we would see more incidents." Most of the 75 incidents occurred from July 1989 to April 1991 on McDonnell Douglas MD-80s shuttling between the airline's home port in Seattle and various cities in California (with 22 occurring on Boeing jets), but three test flights and collections of air samples failed to isolate a cause.

The randomness of the illness complicated the investigation—the airline often went weeks without an incident. Also, symptoms varied among attendants. On one flight, for example, one worker felt lightheaded, another reported headaches and fatigue lasting for days, and the rest of the cabin crew felt fine. Although most victims were able to return to work within hours or days, three attendants are still too sick to return, says Terry Taylor, the airline's representative

in the Association of Flight Attendants union.

No passengers reported any illness, and only a few cockpit personnel have noted any symptoms, Taylor says. She believes only attendants are getting sick because they are exerting themselves while passengers remain seated.

Although NIOSH reviewed each victim's medical records and checked theories blaming everything from monosodium glutamate in food to carbon monoxide in the cabin, Sussell says, "we basically came to the conclusion that there was not an air quality problem we could identify the source of." Inconclusive findings are common in indoor air quality investigations, which doesn't mean claims of illness aren't valid, Sussell adds, but it does mean the agency doesn't plan to continue investigations.

The AFA isn't satisfied, however. Although incidents dropped from 10 a month in April and May 1990 to one in July 1991, Matt Finucane, the union's director of safety and health, still believes the problem is related to air quality. "We appreciate the fact that NIOSH looked into the subject," he says, but "we're not happy with the study in the sense that they only studied three test flights."

Alaska Airlines vice president of in-flight services Bill Cox is grateful that the complaints have dropped off but is concerned that he still doesn't have a culprit. "You could characterize us as somewhat frustrated," he says. "The good news is we're heading in the direction of having it go away. I can live with a lack of answers as long as the problem goes away."

—David Volk

Update

Does This Mean the Recession Is Over?

Nearly half of the 65 vintage aircraft for sale at the second Museum of Flying auction in Santa Monica, California, last October were snapped up (Soundings, August/September 1990). A Ford Tri-motor went for $650,000, while a newly manufactured Soviet Yak-3 and a Helio Stallion once owned by the Central Intelligence Agency sold for $440,000 apiece. However, a B-17 whose owner expected $1.5 million went unsold.

Satellite Hunting...

On September 13, 1985, an F-15 Eagle flying off the California coast pulled up until its nose pointed into space, then fired a missile at a satellite some 320 miles above and blew it to pieces. It was a stunning, if controversial, technological demonstration, and the first U.S. interception of a satellite. It was also the last—several months later Congress banned testing of the weapon against targets in space.

"To have it finally work, and that be really the death knell of the program...was very, very hard to deal with," remembers Air Force captain John Hyten, who served as the last chief engineer on this anti-satellite program. Hyten now works at the Pentagon, but one of his last duties on the project was to send an ASAT missile to the National Air and Space Museum.

Currently in storage at the Museum's Paul E. Garber Facility, the missile measures almost 18 feet in length and one and a half feet in diameter. Black and white stripes extend from its tan nosecone to four tail fins in the rear. Though it looks identical to the five that were eventually launched from beneath F-15s, the Museum's missile was never deployed. It was attached to an F-15 to determine heat loads on the missile's sophisticated infrared sensor system and the missile's behavior under various F-15 launch maneuvers.

The acronym ASAT refers not to any single missile but to a range of anti-satellite weapons that can be launched from earth or space. An inevitable consequence of the 1957 lofting of Sputnik, the first anti-satellite missile was developed by the Air Force two years later. The intended prey were Soviet military satellites, including low-orbiting photo-reconnaissance, electronic intelligence, and ocean surveillance spacecraft. The Soviets had their own versions of ASAT and conducted dozens of tests.

Different types of satellite killers were developed in the United States over the years, but the F-15 air-launched missile was the most sophisticated. The missile consisted of two off-the-shelf booster stages—a Short Range Attack Missile (SRAM) motor first stage and an Altair III second stage—and a miniature homing vehicle (MHV), which included a sophisticated infrared sensor system and 64 tiny solid rocket motors.

The first launch from an F-15 was made in January 1984, when an ASAT missile was aimed at a pre-determined point in space. Later that year a second launch targeted the infrared signature of a star. The third target was P78-1, also known as the gamma-ray spectrometer satellite, which the United States had launched in February 1979. Traveling at 17,000 mph, the one-ton, 11-foot-long, six-foot-diameter satellite was in a circular polar orbit when the F-15, flying at just under Mach 1 in a 60- to 65-degree climb, launched its missile. The first and second stages separated and the MHV homed in on the satellite at almost 11,000 mph, destroying it on impact. While the test was cheered by the Pentagon, it was criticized by both arms control advocates and solar scientists involved with the satellite, which was still transmitting data.

Two subsequent tests targeted the radiant energy of stars, but the Congressional ban eliminated further testing against satellites. The Air Force turned its attention to ground-based laser anti-satellite technology, and eventually the ASAT air launch program was shelved. The MHVs, missile combinations, and test missiles are now scattered across the country in weapons bunkers and museums.

This 1985 launch from an F-15 marked the high point of the air-launched ASAT program.

U.S. AIR FORCE

...and Satellite Fishing

Thanks to a LACROSSE radar satellite, Desert Storm military brass were informed of Scud missile attacks within 120 seconds of launch. Flying 400 miles above the Middle East, the sophisticated satellite played a major role in the Gulf war by relaying information directly to the battlefield via mobile receiving stations (see "The Spies in Space," p. 74). It was a great technological leap from the days when a payload capsule was released by an orbiting satellite and literally hooked in mid-air by airplanes.

"It would be just like a fish hitting a fishing line," says Bob Flavell, a retired Air Force technical sergeant. As a member of the 6594th Air Force test

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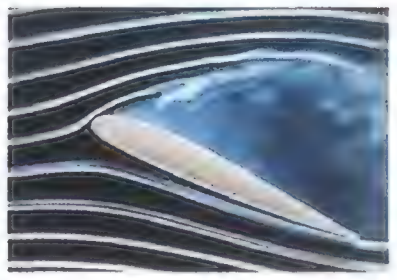

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ED MARSHALL

Aviation pioneer Glenn Curtiss briefly enjoyed the title of fastest man in the world, and the vehicle that earned him this title is on display at the Museum's Paul E. Garber Facility in Suitland, Maryland. Powered by a 40-horsepower V-8 air-cooled engine, the motorcycle features enormous handlebars on a frame that extends more than seven feet, a friction brake on the rear tire, and no shock absorbers. On January 23, 1907, at the Florida Speed Carnival in Ormond Beach, Florida, Curtiss attained the unheard-of speed of 136.3 mph on a five-mile stretch of beach. The next day the Chicago Daily News *reported: "Bullets are the only rivals of Glenn H. Curtiss of Hammondsport."*

group, Flavell was responsible for the mid-air recovery of film capsules dropped from orbiting satellites. From 1968 to 1979, he participated in the recovery of a half-dozen payloads, and recently he donated to the Museum a hook that was used to snag the parachute shroud of a satellite capsule.

Measuring about eight inches, the solid brass hook has four tines and resembles a boat anchor. An 18-inch looped length of hemp rope connected the hook to a trapeze-like device, which was lowered from the rear cargo door of a C-130. As many as eight hooks were used to ensure a successful fishing trip.

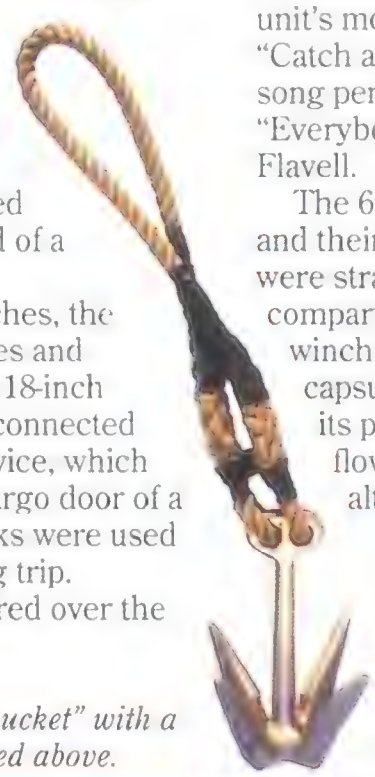
The capsules were recovered over the Pacific Ocean near the 6594th's home at Hickam Air Force Base in Hawaii. The unit's motto, appropriately enough, was "Catch a Falling Star," from a popular song performed by Perry Como. "Everybody had that record," remembers Flavell.

The 6594th had about a dozen C-130s, and their crews included five men who were strapped into the airplane's aft cargo compartment to operate a heavy-duty winch, which retrieved both the capsule, known as "the bucket," and its parachute. The missions were flown at about 150 mph and at altitudes under 15,000 feet.

During his 11 years at Hickam Air Force Base, Flavell was involved in recovering both intelligence satellites and biosatellites, which contained both plants and animals. "The one I liked best was going after the monkey—Bonnie the monkey," he says. "It was like you had someone's life in your hands."

The retrieval method used by the 6594th dates back to August 1961, when a C-119 Flying Boxcar retrieved the reconnaissance satellite Discover 13. Last summer, when Flavell visited the Museum and noticed that its Discover 13 exhibit didn't include a hook, he donated the one he had received from the 6594th. "I can always go down and see it and say hi," he says.

—David Savold



A C-130 goes fishing for "the bucket" with a hook similar to the one pictured above.

U.S. AIR FORCE (HOOK: MARK AVINO)

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700.

New IMAX film *Antarctica* features spectacular footage of the frozen continent. Langley Theater, 6 p.m. Tickets: $3.75 adults; $2.75 children, students, and seniors.

New Film Series The 1992 Space Fiction Film Series salutes Star Trek and its 25th anniversary and features motion pictures, television episodes, and lectures. Langley Theater, every Friday, beginning January 10, 8:30 p.m.

December 7 Monthly Sky Lecture: "A Star Who's Worth's Unknown." James H. Sharp, NASM. Einstein Planetarium, 9:30 a.m.

December 12 General Electric Aviation Lecture: "Serious Fun and Professional Aerobatics." Patty Wagstaff, national aerobatic champion. Langley Theater, 7:30 p.m.

January 4 Monthly Sky Lecture: "Black Holes." Minas Kafatos, George Mason University. Einstein Planetarium, 9:30 a.m.

January 16 General Electric Aviation Lecture: "Fire Safety." Constantine Sarkos, Federal Aviation Administration. Langley Theater, 7:30 p.m.

February 4 Wernher von Braun Memorial Lecture: Title to be announced. Norman Augustine, Chairman and CEO, Martin Marietta Corporation. Langley Theater, 8 p.m.

Planning a Smithsonian Visit? The new VHS video *Guide to the Smithsonian* is an excellent aid for pre-visit planning. For ordering information and the free Associates' Planning Packet, write to Associates' Reception Center, Smithsonian Institution, Washington, DC 20560, or call (202) 357-2700. Hearing-impaired visitors can use TDD and call (202) 357-1729. Begin your visit at the Associates' Reception Desk, which is located in the Smithsonian Castle and open 9 a.m. to 5:30 p.m.

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By Airship to America

It was a matter of Cambridge regulations. In the summer of 1936 my brother was getting married in Canada and I was to be best man. We were both booked on the *Queen Mary,* but at the last moment I found that I couldn't go by ship. I had taken my final exams, but to get a degree one had to spend 56 consecutive nights from midnight to 6 a.m. within the college. If I took the *Queen Mary* I would be one night short, and the next ship to Canada was a slower vessel, which meant I would not get to Toronto until after the wedding. It looked hopeless.

Then my father saw a notice about the *Hindenburg,* airship number 129 of the German Zeppelin fleet. At the time passenger aircraft could not fly the Atlantic in one hop, but an airship could manage it. In fact, it looked like airships might be the future of travel. I certainly thought so.

The *Hindenburg* was to make its third North Atlantic crossing at precisely the right moment to solve my predicament. A final 56th breakfast at Cambridge, an Imperial Airways biplane to Paris, a train to Frankfurt am Main, and my father and I were at the hangar with nearly an hour to spare. The fare was £80, roughly twice as much as second class passage on the *Normandie,* on which I later returned.

I knew the *Hindenburg* was big, but I didn't realize *how* big until I saw the nose sticking out of the giant hangar. The airship was just over 800 feet long, four-fifths the size of the *Queen Mary.*

Before boarding I had to step on the scales. Every individual, suitcase, and crate of cargo and provisions was carefully weighed—all in all, passengers and freight accounted for nearly 20 tons. At takeoff, the airship weighed 240 tons.

The *Hindenburg* carried just over 50 passengers—and a crew of 45! The ground crew walked the ship from the hangar, and we boarded by a stairway in the belly. The undercarriage and tail rested on two trolleys, and the crew held the ropes attached to the nose to steady it in the event that a gust of wind arose. When we were all on board, the airship was detached from the mast and trolleys.

Captain Ernst Lehmann leaned out the window of the gondola and signaled the ground crew foreman, who blew his whistle. Half a ton of water splashed down from the ballast tanks to boost the ship up before the 16 hydrogen bags in the hull began to lift it.

There was absolute silence within the ship and on the ground. Very slowly we rose, and the faces of those seeing us off grew smaller. The engines had not yet started as we drifted into the evening sky. At about 200 feet some hydrogen was released to reduce the lift, the four diesel engines outside the hull roared to life, and we swung toward the sunset and the Rhine.

Inside the hull were two decks with windows, three of which could be opened. The upper deck had two 50-foot promenades with a dining salon and a lounge, complete with aluminum grand piano. Twenty-five heated cabins with double berths had sinks with hot and cold running water. I leaned on a window sill and stared down in fascination at the Rhineland countryside passing not far below in the dusk. Shining down from the nose was a powerful searchlight that brilliantly lit a circle of land. I saw woodlands and a bend of the great river where we crossed it.

The legendary airship pioneer Hugo Eckener was a passenger on this flight. "You have seen the cathedral of Cologne?" he asked me. I said I had not. "Then I think we take a look at it," he said.

"Europe to America in under 60 hours—incredible!..."

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"...a lounge, complete with aluminum grand piano..."

Two hours after we had lifted off we came to the suburbs of the great city, then cut across the river. The two spires of the cathedral rushed into the circle of light and out into the blackness.

I stayed at the window through the night, just watching. I saw Rotterdam, with big ships lying alongside the wharves in a haze of smoke, then here and there the flash of a small Dutch vessel in the North Sea. Eventually we reached the English coast over the flames of Middlesbrough's blast furnaces, and soon we were crossing the wild moorlands of the Pennines. It was dawn when the sands of the Solway Firth shone up to us. We cut across the southwest tip of Scotland and out into the Atlantic. When the sun rose astern there was no land in sight.

It was not until the third day that we reached Newfoundland. We saw very little—the island was shrouded in cloud, with only a rare parting that revealed the forests. But even above the clouds I could tell just how high we were merely by glancing at my watch. Instead of an altimeter the airship had an echo sounder, which directed a compressed-air whistle earthward. After striking the sea or the ground, the sound bounced back to the hull. The interval that passed between the outgoing signal and the return automatically recorded the altitude in the control cabin. Knowing that sound travels roughly 1,100 feet per second, I was able to make the calculation myself. An interval of two seconds meant we were at about 1,100 feet.

"...I stared down in fascination at the Rhineland countryside..."

Weight and balance are concerns with any aircraft. A conventional airplane uses fuel on its journey and so becomes lighter. Less power is needed to keep it flying, and the landing is easier when a ship is not fully loaded. But an airship has to maintain a certain weight to prevent it from rising too high. Any weight lost through fuel consumption has to be compensated for. An obvious solution is to valve off hydrogen to reduce lift, but this decreases the margin of safety, and the airship would have to refill with hydrogen before making the return trip.

To maintain altitude, the *Hindenburg* would brush against rain clouds and collect rainwater in gutters that fed the ballast tanks. If the airship passed through a shower every few hours there was no need to valve off expensive gas. Of course, there were occasions when no rain was available, but on our flight we were never too far from a suitable shower.

On our third night we neared the New England coast. I had told Eckener that my brother was aboard the *Queen Mary,* heading for New York. "I think we visit the bridegroom," he said now, smiling. About two hours out of New York we caught up with the ship in the dark, and as our searchlight beam ran up on it the ship's crew turned on the floodlights.

Just after dawn we came in right over the Statue of Liberty. I gazed out across New York harbor at the mass of skyscrapers on Manhattan. Then we turned, slowly losing altitude, until we saw the Lakehurst airfield in New Jersey with its mobile mast, to which the *Hindenburg*'s nose would be moored. The ship came up into the wind and the engines slowed until we were hovering at about 200 feet. When we were quite still some hydrogen was valved off and the great airship began to descend, slowly at first, then faster. Some 250 men raced across the grass to grab the landing lines dropped from the nose. Only when we were perhaps 30 feet from the ground was the fall checked by releasing a shower of water. We landed on the single wheel beneath the gondola with a gentle bump. The ground crew hauled the ship toward the mast and shackled it.

Europe to America in under 60 hours—incredible! We had achieved a sensational average speed of 68 mph from Frankfurt to Lakehurst. But the *Hindenburg* was to make only another eight crossings. On May 6, 1937, it fell in flames over Lakehurst after waiting for storms to clear the area.

I felt I had lost a friend. More than that, I knew airships were finished. The next generation would never see that enormous shape in the evening sky, hear the curious squeak of the echo sounder above the clouds, see the broad shaft of light shining down from the nose.

Twenty years later I was flying the Atlantic in a Constellation. The flight attendant pointed out the window at the southern tip of Newfoundland. "That's Cape Race," she said. "We'll be landing in a couple of hours or so." Watching the lighthouse fade away, I recalled how Eckener had come up behind me in his great fleecy jacket as I peered down through broken clouds. *"Kap Rasse, mein Herr.* In 16 hours we shall be landing. Perhaps sooner."

—Roger Pilkington

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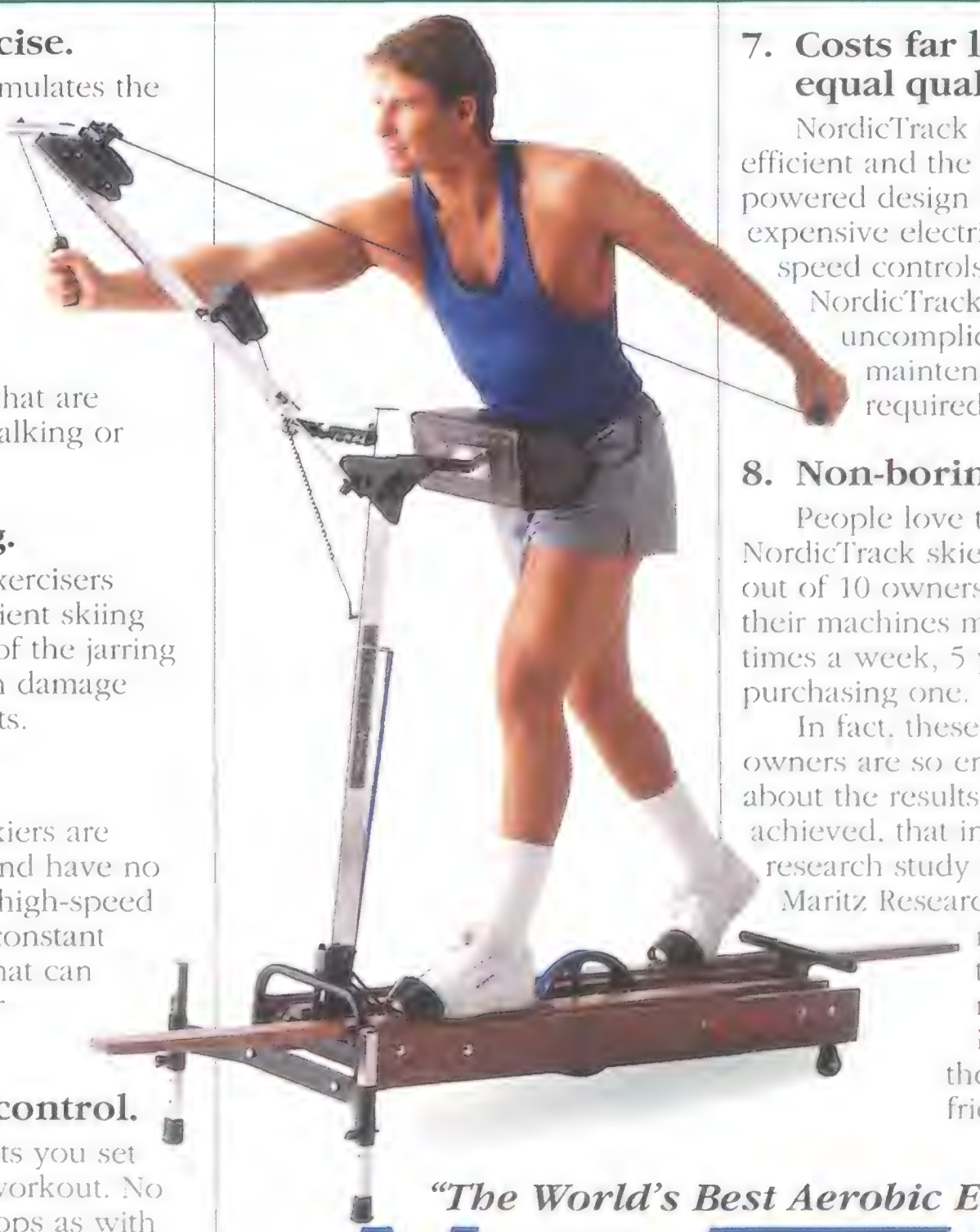

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Out for a Spin

DAVID CLARK

If I have a weakness (perish the thought) it may be that I am inclined to make an exhibition of myself. That inclination has been getting me into trouble for years, but 1959 to 1961 was a vintage period. That was when I served as an exchange flight commander with the 3615th Pilot Training Squadron at Craig Air Force Base in Alabama. As the only uniformed Brit for miles around, I tended to attract curiosity, and I went to some pains not to disappoint. I grew a handlebar moustache, flew the Union Jack in my flight shack, and insisted that the flight's call sign be "Royalist."

My American superiors tolerated my eccentricities, but when they discovered I had a history of showing off in airplanes, their indulgences went too far. To my surprise, they invited me to do aerobatics in a Lockheed T-33 jet trainer at the base's next Armed Forces Day.

I was flattered. I told my commander it would be a piece of cake. He, sensible man, was not so sure, but when the festivities came I did my bit without raising his blood pressure too high. Of course, I never told him the trouble I got in working up my routine.

The problem was that the T-33 was somewhat of an unknown quantity for me. Most of my time in it had been spent qualifying as an instructor, and my mentors had insisted that I fly it by the book. Aerobatics had been disguised as precision maneuvers. A loop was not a loop unless it started and finished at 350 knots (349 would not do). Free expression was frowned upon. Now, suddenly, I was asked to perform maneuvers that were not in any textbook, and apart from a brief and rather vague reference to something called an "out of control" maneuver, the flight handbook was less than helpful. I decided to go off by myself and experiment.

After a few aerobatic sorties, I convinced myself that the T-33 was innocuous. I built up a sequence that included an eight-point roll, a vertical eight, and a series of slow-speed aerobatics. To keep the show tight, I reversed direction after each run with a stall turn (a hammerhead in the United States). It was these stall turns that raised the eyebrows of my colleagues. One was not supposed to fly the T-33 with no indicated airspeed.

About this time I happened to fly a sortie as safety pilot while my assistant flight commander, a splendid Mississippian known as Whitey, got some instrument practice. On the way home he asked me to demonstrate some of my sequence, particularly "that stall turn." We were in a T-33 fitted with tip tanks and were a bit high—around 14,000 feet—but I didn't think it would matter. The Meteor I had flown, the performance of which was fairly similar, had always behaved itself at altitude. I scanned for traffic, tightened my seat belt, and pulled the aircraft vertical, giving a running commentary. "Check the wings at right angles to the horizon...Watch the airspeed...As it falls through 180 knots feed in left rudder...Keep going to full rudder...As the nose sweeps sideways through 45 degrees cut the power to bring the nose down sharply—Damn! It's stuck."

The T-33's nose had moved to about 30 degrees from the vertical and stopped. I recognized the symptoms. The Meteor did this sometimes. No problem. Just neutralize the controls and wait until the nose falls through (the Meteor's always did), then try again. The airspeed indicator showed zero and fuel from the engine compartment began to flow forward over the canopy. It was remarkably quiet in the cockpit. Then all hell broke loose. The nose pitched up violently. With no airspeed, I was astounded to see that the G meter registered +4. We were falling end over end, rotating around the wingtips. I hardly had time to draw breath before the rotation stopped, but the aircraft was vibrating so much that the tip tanks were a blur. My wonderment at the sight was not prolonged. Suddenly the rotation began again, this time nose down.

In the back seat, Whitey's monumental calm lapsed for just a moment. Negative Gs had drawn everything out of the rear storage pockets and he was covered in unfolded maps. "Have you got it, Ron?" he asked mildly. "I'm trying," I said through clenched teeth. What was that the handbook had said about "out of control" maneuvers? Rudder and ailerons neutral and stick fully back. We fell some more. It wasn't working. In desperation I pushed the stick full forward. After an eternity the tumbling smoothed out. At last I recognized something: an inverted spin. I held the T-33 in the spin for two full turns to make sure it was established, then started the recovery.

As the spinning stopped I pulled the aircraft into level flight. Whitey decided we would not be ejecting and took his hand off the handle that would have blown the canopy away. We were down to 5,000 feet or so, the cockpit was full of smoke, the powered ailerons had given up and reverted to manual control, and the engine sounded like it had ingested a bucket of bolts. Never mind. It was flying.

—Air Vice Marshal Ron Dick
Royal Air Force (ret.)

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The Drug FIGHT

Enlisting a piece of its small air force, Bolivia warily increases pressure against the flow of cocaine from its jungle territories. As the pressure builds, the country braces for war.

by Carl Posey

photographs by Chad Slattery

Outside the Air Force Academy buildings at El Trompillo airport in Santa Cruz, Bolivia, two fabric-covered biplanes tremble in the hot, humid air. These Stearman PT-17s, World War II-vintage trainers, are residues of the old Bolivian Air Force, which fired its last shot in anger some 60 years ago, during the Chaco war. That border conflict with Paraguay lasted from 1932 to 1935, killed 100,000 Bolivians, and, like nearly every war fought by this small, penniless country, was lost. Since those days, the air force has evolved into an armed public works corps, using its aircraft less to defend the borders than to supply and transport people who live in the rugged interior. For rural Bolivians, the air force has been a benefactor and lifeline. It is

Flying over the Chaparé River valley, a Bolivian air force helicopter casts an ominous shadow on a legal coca farm.

the air force, for example, that today ferries medicine to villages in the path of Peru's southward-creeping cholera epidemic.

A symbol of this humanitarian brand of military aviation rests in a dusty traffic circle outside the Jorge Wilsterman airfield in the city of Cochabamba: a B-25 Mitchell, retired in the late 1970s, having never dropped a bomb. The Bolivians used their fleet of B-25s as transports. Today's Bolivian air force, however, is making a different kind of monument. One day, outside the gate at El Trompillo, there will no doubt be a mothballed Bell UH-1H Huey. The helicopter that will always evoke Vietnam for Americans will commemorate in Bolivia a war that one unit of its air force began to fight in the middle of the 1980s—a war that may prove no more winnable than the Chaco campaigns.

The combat-bound unit is the Red Devils (Diablos Rojos) Task Force, and their task is to stop the export of Bolivia's largest cash crop, coca leaf, and the powder into which it is processed, cocaine. So far the Red Devils have been a support group, transporting soldiers from Unidad Movil de Patrullaje Rural (UMOPAR), a regional anti-narcotics arm of the national police, into the wild northeast corner of Bolivia, where the labs of the cocaine traffickers hide in the rainforest. The UMOPAR soldiers confiscate the drug and paraphernalia, arrest any traffickers who had not been tipped off about the raid, and torch the labs. But first they have to find them.

To search out such targets, the Red Devils fly more or less constantly, operating out of two bases: one at Chimoré, near the Andean foothills along the Chaparé River, and the other in Trinidad, well to the north, almost submerged in the bog of a lowland rainforest. Their theater of operations is roughly the northeastern quadrant of the country, the area called El Beni. The pilots patrol from Santa Cruz, effectively the traffickers' corporate headquarters, to Trinidad and beyond, and through the coca-growing lands around the Chaparé.

The Red Devils Task Force is commanded by Bolivian air force colonel Adolfo Perez Saldias, a man of great seriousness and, it turns out, warmth and good humor. "We have developed criteria for the laboratories," Perez explains. "They are near a river...a lagoon...and usually on relatively high ground. The helicopters go in within a kilometer of such places, then they move in and their downblast blows the trees open to reveal laboratories. So when we discover the labs, the helicopter goes down as low as possible and the troops rappel down."

Here in the rainforest, and in neighboring Peru and Colombia, is the supply. The demand of course is far to the north. In a way, this war, like aid money and Coca-Cola, is a gift from the people of the United States, whose appetite for cocaine has created a multibillion-dollar farm-to-market industry. For the eternally impoverished *campesinos* of this impoverished land—in this hemisphere, only Haiti is poorer—the cash crop is simply unbeatable. Bolivia produces probably one-third of the world's cocaine. But ask any Bolivian whose problem all this is and he will tell you it is North America's, adding that there is no cocaine problem in Bolivia. Thus the Red Devils fly U.S. helicopters, are trained by U.S. pilots, and, along with a unit of the navy called the Blue Devils, are guided and supported by U.S. advisors, who operate out of the U.S. Embassy in La Paz under the aegis of the Department of State's Office of In-

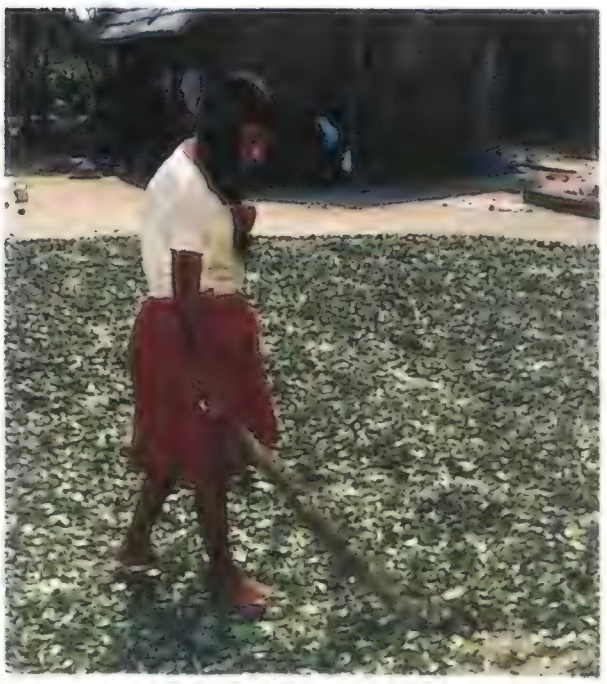
The War Zone

Operating from bases at Chimoré and Trinidad, the Red Devils carry antinarcotics police over El Beni to search for drug laboratories. Drug labs are relatively new in Bolivia. Until a few years ago, traffickers bought coca in the Chaparé River area and exported it to Colombia for processing. Now they transport the leaves to jungle labs, usually in the rugged, roomy Cessna 206. There the leaf is made into paste or the final product, cocaine.

ternational Narcotics Matters.

Tony Burgess has directed the office's Narcotics Affairs Section since October 1990, his first assignment in what he and his state department colleagues call "the drug fight." A middle-size man with longish brown hair, a tough, intense aura, and a wardrobe from Indiana Jones—leather jacket, crumpled hat, and khakis—he graduated in West Point's class of 1969 and wears the big Army ring with an infantry-blue stone. Forced out of the infantry as a captain by knee injuries from football and jump school, he took the foreign service exam and moved to the state department, where he is in "administration." His career resounds with turbulent posts: Beirut, El Salvador, and, before La Paz, Guatemala. He says he likes the long days and long weeks in what is becoming a very busy place, drug fight-wise.

The first U.S.-supported military action against Bolivia's cocaine traffickers was taken in 1986. Operation Blast Furnace was a joint effort with U.S.



A pre-Columbian crop, coca is cultivated in Bolivia along the eastern edge of the Andes.

Army helicopters and crews ferrying Bolivian police into the Beni to burn the traffickers' labs. The Red Devils Task Force, not formally established until 1987, got its start at about that same time, with a few U.S. instructor pilots and a handful of machines.

Since then, the Bolivian government

Four aircraft currently flown by the Bolivian air force: (clockwise from top) an F-86, T-33, T-23, and PT-17.

Coca tea bags, sold throughout Bolivia, provide a mild stimulant that eases the symptoms of altitude sickness.

has tried to maintain a delicate balance between preserving the culture and economy of its jungle farmers and getting tough with traffickers. Under a 1988 law, Bolivia strengthened controls over coca production, part of which serves a perfectly legal domestic market. *Erythroxylon coca* is a pretty little cream-flowered, red-berried bush that has been grown along the Andes for centuries. People chew its leaves to relieve the indescribably hard life of the long, high, moon-like Altiplano and to stave off *soroche,* an incapacitating malaise resulting from oxygen deprivation. Coca tea bags are sold like Lipton's, and the reviving brew is served everywhere, even in the U.S. Embassy in La Paz.

Following the 1988 legislation, the plants on the northeastern flanks of the Andes, a strange and beautiful land called the Yungas, would continue to produce coca for the domestic market and for medicine. But new coca plantings elsewhere were decreed illegal, as

was the processing of coca into anything closer to cocaine. In the spirit of targeting the traffickers instead of the farmers, the new law also ruled out spraying coca crops, an issue sensitive enough to ruin any chances for cooperation. Instead, the planting restrictions are enforced by an office in the Ministry of Campesino and Agricultural Affairs. DIRECO (Regional Office for Coca Control) persuades *campesinos* to eradicate their illegal crops voluntarily or eradicates the crops for them. (DIRECO also registers the growers, measures fields, certifies eradication, and keeps the country's records of coca production.)

"We're not planning to use Hueys to carry the eradication people in," says Burgess. "They go in on trucks, usually a three- or four-person cadre from the national agency that comes in and hires locals to do the cutting and uprooting of coca plants. The DIRECO people talk to leaders of the coca syndicate—it's like a farm co-op—tell them that the crop is illegal and, under the law, has to be destroyed. The *campesinos,* the leaders, know it is illegal and acknowledge the government's right to eradicate it."

Forced eradication is necessary only when the price of coca is high, as it is now. Since coca is a commodity, like soybeans or tobacco, its price varies, and with it the observance, or breach, of the law. When the price is down, as it was a year ago when a hundred pounds of leaves brought only 70 or 80 bolivianos (about $20), the *campesinos* follow the righteous path of crop substitution and dutifully destroy their coca fields. They are paid a bounty of $2,000 for each hectare (about two and a half acres) voluntarily taken out of coca production. When the price is up to, say, 200 bolivianos the hundred-weight, crop substitution is less attractive, and production increases. Often, farmers try to keep their personal economies balanced: they destroy part of their coca plantings for crop-substitution incentive money but keep a bit of coca growing on the side.

The war see-saws the same way. When crop substitution seems to work, the emphasis is on interdiction. The police cease pummeling the farmers and take off after the traffickers. That's where the Red Devils come in, with three or four of their 16 Hueys carrying perhaps 20 UMOPAR police on a daily aerial browse.

Although a *campesino's* share is only a fraction of Bolivia's huge income from the cocaine trade—the real wealth flows to the traffickers—it often means survival to his family. This spawns a sad irony: It puts the coca farmer on the enemy side of the drug equation, and raises the specter of combat. Thus, after a long-standing friendship between a civilian population and a military force—a friendship that may be unique in Latin America—the Red Devils may now have to fight the very countrymen they once served.

"We have good relations in Cochabamba and all the towns in the Beni that are not used by the *narcotraficantes,*" says Perez. "They are in sympathy with the air force because there are no roads. But towns like Santa Ana...they are against us." He adds, then, perhaps to distance himself from the men his helicopters carry to the fight, "The Red Devils take nothing. We leave all the equipment, everything. Generators, radios, kitchens, refrigerators, narcotics... we take nothing."

But the police they take into the Chaparé and the Beni leave nothing. Often, when the traffickers are driven out of the villages, the local economy goes with them.

The Beni village of Santa Ana de Yacuma, a town of about 15,000 located a hundred miles north-northwest of Trinidad, has been the main target of the Red Devils since they started flying, and the series of raids against the town has formed the pilots' learning

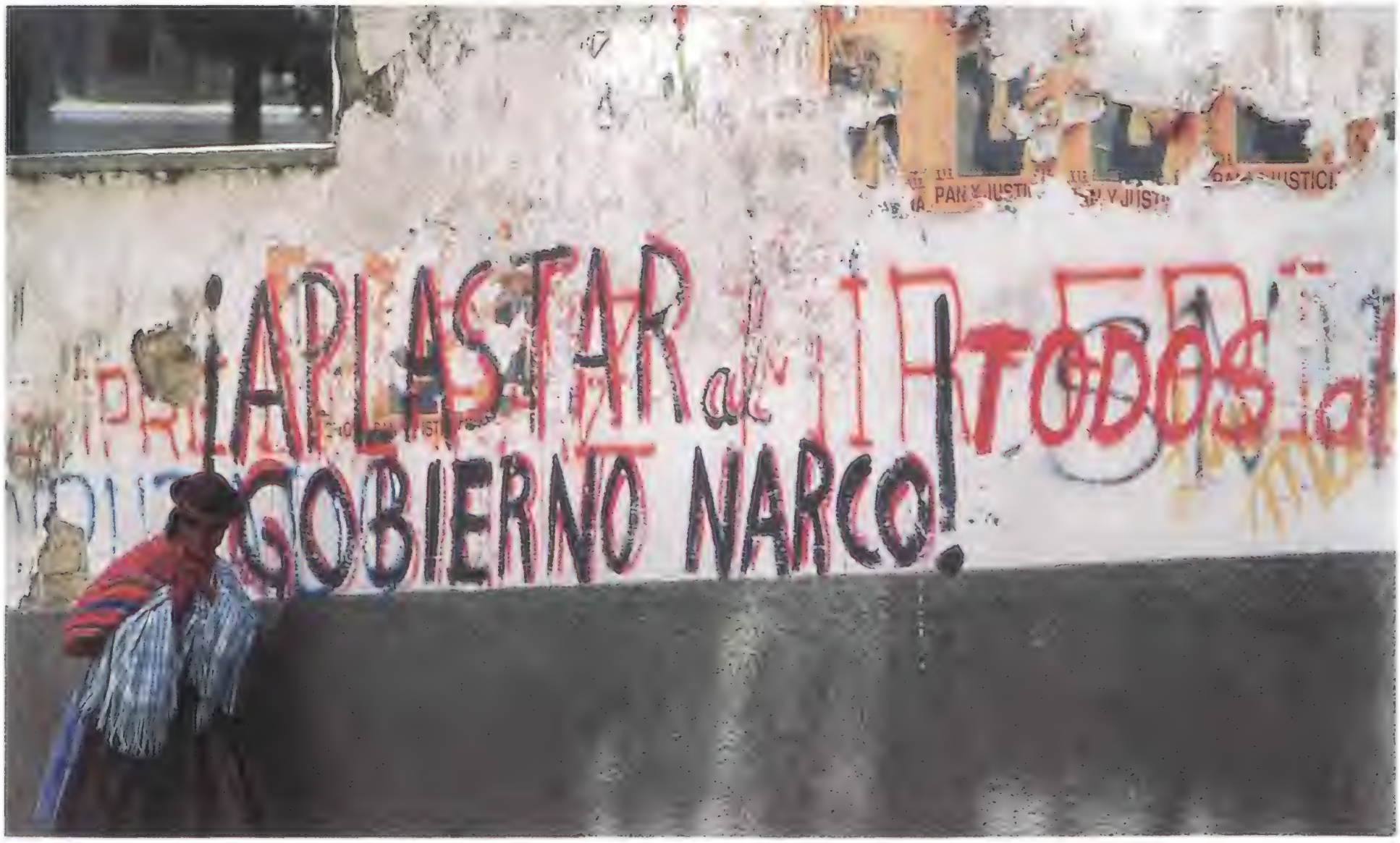
"I think now we have to be very careful," says air force colonel Adolfo Perez Saldias (above), as Bolivia tightens controls on cocaine.

In Chimoré, UMOPAR soldiers line up for inspection (right).

Patrolling the jungle near Santa Cruz, Red Devils in a Bell UH-1H Huey look for drug labs (opposite).

curve. A dusty little community of unpaved streets and adobe buildings with red tile roofs, low-lying Santa Ana is surrounded by a dike to protect it during the rainy season from the Mamoré River. But Santa Ana is ringed by more than a dike: for a hundred miles around it, the Beni is dotted with the ranches and labs of the drug traffickers. Called the Medellin of Bolivia, Santa Ana makes its living off the drug trade and does not welcome attempts to restore government control.

The first helicopter assault on Santa Ana was made in 1987, when Red Devils and UMOPAR soldiers—everyone but the U.S. advisors—were as green as rainforest trees. The idea was for UMOPAR to seize aircraft at the Santa Ana airport and vacuum-search them for drugs. But hundreds of townsfolk—estimates range from 500 to 1,000—swarmed to the airport, surrounded the drug dealers' Cessnas, and prevented a Bolivian air force helicopter and a C-130 from taking off. Other members of the Red Devils had to fly in to rescue the crews. "We were going down into 300 people and picking up our guys," recalls one former U.S. instructor. "They were hanging on the skids, people throwing rocks at us." He breaks into a broad grin at one memory of the melee. "My



Graffiti in La Paz, probably painted during the 1980 reign of Garcia Meza, urges: "Smash the narco government!"

Traditionally chewed by natives in the Andes, coca leaves are now harvested for wider use in tea.

[Red Devil] pilots saw the flashes of guns—they thought they were flashbulbs, somebody taking pictures." The mission collapsed. The Bolivian government forces and their U.S. collaborators left the Cessna 206s where they were and withdrew.

In mid-June 1989 they went back, this time to bag narcotics kingpin Hugo Rivero Villavicencio, and were met by armed resistance, including fire from a unit of the Bolivian navy, whose commander later said, not very convincingly, that he thought the advancing UMOPAR forces were an "invasion." Recalls Perez: "We put in six helicopters at 4 a.m., landed outside the town, sent troops in to go to the homes of the people. But their guards had radio and heard our conversations in the machines. So there was resistance; the helicopters were hit in a few places. Much fire in the night. It dispersed our forces. We did not have much control in the

town. We will be seeing more of this kind of thing."

On that night, according to one U.S. embassy official, the *narcotraficantes* used villagers as human shields, and the U.S. Drug Enforcement Administration operatives and UMOPAR generously held their fire. On that operation, nobody mistook the flickering lights for flashbulbs.

Those early forays constituted the Red Devils' basic training. In mid-March 1991, the largest operation of the drug fight in Bolivia got under way. Called Operation Safe Haven, it began with strikes on trafficker laboratories scattered around the wilderness of the Beni. Soon afterward came a search and seizure of airplanes at the Trinidad airport. In all of Operation Safe Haven, 42

aircraft were confiscated, most of them Cessna 206s. The operation netted about half the trafficker air force, officials say.

On Friday, June 28, the law went back to Santa Ana, this time with a force of some 640 people, most of them UMOPAR national police, a score of DEA agents, and the Bolivian Devils, Red *and* Blue, in a rare combined operation. The navy went in first, delivering 54 UMOPAR officers to the naval base at Santa Ana, "with a Bolivian navy captain along to assume command...to make sure there was no repeat of 1989," recalls U.S. Embassy press attaché Bruce Wharton, who flew in hours later. "Then the special teams, each with a specific target—a suspected drug trafficker's house—moved on their targets."

Meanwhile, just before legal daylight at the Trinidad city airport, where the Red Devils have a base, 12 Hueys lifted off, each carrying six UMOPAR officers, for the 50-minute flight to Santa Ana. "They got there about 5:45 and took control of the airport and detained suspects there," says Wharton. Three Bolivian C-130s followed, bringing 200 police, as well as fuel blivets from which to refuel the Hueys.

Once those pieces were in place, the Red Devils fanned out in sorties of four Hueys to probe ranches and laboratories thought to belong to traffickers. "Those operations continued all day," says Wharton, who flew on two sorties as the Devils continued their ferreting through Saturday, working out as far as a hundred miles from Santa Ana. "By Saturday morning," he notes, "there was a pretty good influx of informants, who came in to sell information to UMOPAR about lab locations—wanting to make that last dollar."

While the national police held the town (and evidently showed restraint when crowds of angry Santa Anans confronted them until dispersed with CS gas, a substance akin to tear gas), UMOPAR teams accompanied by Bolivian attorneys made the rounds. By the end of the day they had seized 10 houses, 28 airplanes, and a quantity of radios, spare parts, and vehicles. They also seized seven hangars, one of which they turned into a barracks-*cum*-mess hall that to this day maintains the government presence there.

A textbook operation, of sorts, without the added price of the ugly battle everybody had expected. The government's pre-operation intelligence had indicated that there were about 60 well-armed Colombians in town, but evidently they vanished before the cops arrived. So did the traffickers, who have intelligence sources of their own. (Many say that the traffickers' wealth has reached into UMOPAR itself.) Not one trafficker was arrested in the Santa Ana raid. They had all been warned.

In the entire operation, the only casualty was a Band-Aid-size wound, probably caused by shrapnel from a CS grenade. The Red Devils performed perfectly, as did the Hueys. Even hot refueling from the C-130 blivets—refueling with rotors turning, a technique that helped litter the Iranian desert with U.S. helicopters 10 years ago—failed to produce an accident.

The man responsible for training the Red Devils is U.S. Army lieutenant colonel Steve Accinelli, the Narcotics Affairs Section's aviation advisor. A new light colonel, Accinelli has been in the Army for 18 years, 17 of them as an aviator. Although new to Bolivia, he had worked for a year out of the U.S. Southern Command headquarters in Panama, where he helped teams from various countries develop "multi-year narcotics programs." Accinelli is aided by three U.S. Army aviators who now work as contract helicopter instructor pilots, training the fixed-wing-qualified candidates from the Bolivian air force to fly Hueys in combat.

Of the Bolivian pilots, Accinelli says, "They are mostly good, solid commercial instrument pilots, maybe a shade older than their American counterparts, all graduates of the Bolivian Air Force Academy. When the program developed, a lot of pilots wanted to go into the Red Devils. They arrived with basic fixed-wing experience, about 200 hours, and have gone on to be pilots in command and sometimes instructor pilots. So it's a fairly high-time group."

Few countries offer the flier so many natural challenges so close together. In the west over the Andes, where the air is a third thinner than it is at sea level, engines gasp for oxygen and wings behave strangely. At 13,000 feet, the western city La Paz is fully two miles higher than central Santa Cruz.

"Ordinarily we fly at about 2,000 feet," says Accinelli, "300 to 500 feet off the ground, which is a very comfortable altitude for a Huey."

North and west of Santa Cruz, where the Red Devils patrol, the flat, low ground steams in the rainy season and burns in the dry, so that the air is almost always hazy with water or smoke. Out here there are no roads, only ox-bowed, clay-colored rivers, which bulge now

Colonel Rojelio Vargas sits in front of a ton of cocaine sulfate base, confiscated in one 12-week period.

and then into sandbar-rimmed lagoons. Suddenly, there will be a vast cleared area of grazing land, or sometimes a jungle plantation, or sometimes a drug dealer's lab.

The farther a pilot ventures into El Beni, the fewer useful landmarks and stretches of dry ground he will find. Furthermore, the land is too mutable to be closely charted. Those twisting brown rivers, meandering in search of the Amazon and the sea, change their shapes from one season to the next. Even current Tactical Pilotage Charts of the area—the 1:500,000-scale aeronautical charts one would ordinarily use to fight an air war—have vast areas of white. The charts evoke 18th century maps of Africa. One expects to see the notation "Here be monsters." The purple circles denoting rural airstrips are everywhere on the blank terrain, marking grass runways of unknown condition. When you land on a rural strip, you take pot luck.

Flying over this wilderness with one of the pilots in a confiscated Cessna, I could see how much the Red Devils are part of the country's heroic flying tradition. Anyone who follows aviation has heard the tales of dead-reckoning flights through cloud-shrouded Andean passes in overloaded DC-3s: Bolivian pilots take off into the muck, climb to this altitude, count to 20, turn to this course, count to 20, turn to that course, climb... It is a technique not much used nowadays anywhere else.

Although this aeronautical style appears to have been trained out of the Red Devils, they are obviously a talented group. They overcome the challenges of weather and terrain not with nerve but with discipline. Accinelli says the unit has accumulated more than 15,000 hours of flying, including combat missions, without an accident.

Gradually, the small force is reaching out into the region north of Trinidad, on the Brazilian border. "As we move farther out into the territory controlled by the traffickers," says Burgess, "we expect it to get more combative. It just shades into more and more trafficker-controlled the farther out you go."

It is the rough country of legend, where, as Burgess puts it, "you go to one *estancia* [plantation], you get anacondas, crocodiles, piranhas, killer bees, vampire bats, scorpions, and bushmasters." In a recent sortie, he says, "the DEA and UMOPAR located the largest lab found thus far in Bolivia. It was on an island in a lagoon. They couldn't reach the island by boat or road, so the helicopters hovered over the lagoon and the men dove into the water, captured the lab and some traffickers." He grins. "Once safe and sound, Vargas told them this was the lagoon with the big crocodiles." He refers to UMOPAR's Colonel Rojelio Vargas, who has done much to reduce cocaine

Tony Burgess (top) is the point man in a U.S. effort to fight Bolivian drug dealers. The characters and scenes in this conflict may seem straight out of "Miami Vice," but the action is real.

Unlike many U.S. cities, the Bolivian capital, La Paz, is not victimized by drug-related violence.

traffic in the Chaparé region and who is widely regarded as one of a rare breed: the incorruptible policeman.

So far the enemy in Bolivia has not displayed the ferocity of the drug lord stereotype. "There are some fancy fortress *estancias* out there," Burgess says, but the operations are usually family businesses, not run by monsters of the kind found in Colombia. They tend not to counter-punch, yielding to such drug war pressures as an increasingly able Red Devil unit by shifting their bases of operation, moving labs, and trading up from the ubiquitous Cessna 206s to faster, twin-engine aircraft. "At the moment the *narcotraficantes* have not responded like their counterparts in Colombia," says Adolfo Perez. "I think now we have to be very careful. There is the example of Colombia. Bolivia has a huge area of jungle and many clandestine airstrips."

The Red Devils have been plagued by the problems of scant equipment. When they announce themselves to the tower, listeners on the other side know they are on their way, and scanning units pick up their air-to-air radio frequencies en route. "We have made 15 to 20 sorties," Perez told me last year, "but the *narcotraficantes* escape by listening. We find meat cooking, coffee warm, but nobody there. We are flying very low, constantly changing frequencies, but they ultimately are able to listen in." Burgess notes that the unit is adding scramblers and upgrading avionics and radio equipment; still, he does not expect victory in the field.

Says Perez, "With the means we have,

there is no way to cover the area out there." Steve Accinelli agrees that too little has been invested to make winning anything like a sure thing. "The real war," he reflects, "is in the States."

Yet Accinelli says he hopes to add 12 Hueys over the next two years to the 16 operating now. In addition, the Red Devils operate five Cessna 206s seized from traffickers and are slowly adding to their aeronautical presence. For example, a DC-3 has been refitted with turbine engines for them, and the United States is lending Bolivia a couple of C-130s for logistics. U.S. help is also being given to render airworthy a fleet of 14 Pilatus PC-7s, two-place turboprop trainers from Switzerland that can double as pursuits. The idea, as Accinelli puts it, is for the Bolivians to gain greater air sovereignty over the Beni.

The more equipped and the more effective the Red Devils become, the more one has the sense that the drug fight is poised here, like a stored substance of terrifying flammability. There is speculation that the traffickers are receiving help from their counterparts abroad. So far the airplanes and pilots are mostly Bolivian, according to Accinelli, or at least Latin American; aircraft of Guatemalan registry have been involved in the traffic. No one knows of any Americans doing the dirty aeronautical work. "Down here, a gringo with an airplane is pretty conspicuous," Accinelli points out.

Last year, the Americans who maintained the Hueys said they expected the Sendero Luminoso (Shining Path) guerrillas, who ride shotgun for the *narcotraficantes* of Peru, to drift into Bolivia, bringing their bottomless cruelty with them. Some members of the maintenance crews had spent time in Peru as well. They are employed by a state department contractor, National Air Transport, Inc., which supports irregular U.S. aviation in trouble spots around the hemisphere. "How much is it now?" one asked his comrade, referring to the going rate for his head in Peru. "Fifty thousand," the friend replied, not without pride. They took satisfaction in telling me that an American journalist took several days to die when tortured by the Senderistas. Things are getting worse in Bolivia, they said; there is more anti-American graffiti in the town, asking the *yanquis* to go home. But they appeared unafraid of the looming violence. Their greatest fear was to be identified in print, a firing offense at NATI. Everybody is afraid of something.

Burgess admits that he has been told

Becoming a force to reckon with, the Red Devils have flown their Hueys against armed resistance since 1987.

U.S. Army lieutenant colonel Steve Accinelli advises the Red Devils on training and operations.

to be on guard in Santa Cruz, and Bolivia has authorized Americans involved in anti-narcotics operations to carry weapons, although not everyone does. "When I go to Santa Cruz," says Accinelli, who is based in La Paz, "I don't carry, or out in the countryside either. But I may change after I get more time in country."

Everyone is conscious of the increasing number of Colombians turning up in Bolivia. "There will be strong organizations from other countries," says Perez. "I believe they will do here what they do in their countries. They are also preparing for war."

"Bolivians see it as a Colombian threat," Burgess says. "In the last few months there have been some tangles. Three between the DEA and Colombian traffickers. UMOPAR killed one [Colombian], and there were two other encounters. The rearming was done by the MILGROUP." He adds that such assistance by the U.S. military—even a support agency like the U.S. Military Group, which also assists in civilian projects, such as digging wells—exacerbates the greatest fear Bolivians have about the drug fight: that it will come under the influence of their own army.

The army in Bolivia has a very different reputation from that of the air force. In 1980, led by military officers with strong ties to drug traffickers, the army overthrew the civilian government and installed what became known as the "narco-dictatorship" of Garcia Meza. Civilian rule was restored two years later, but the memory of a powerful army, which protected and profited from the drug lords, is still fresh in the minds of the people.

The presence of an armed guard at the Red Devils compound in Santa Cruz suggests the fear that the drug fight in Bolivia will trigger the violence that has terrorized Colombia and Peru.

Many Bolivians believe that the United States is pressuring their government to involve its army in the drug fight. The U.S. government withheld $14.7 million in military aid until Bolivia's congress, last April 4, approved the army's participation. The funds were earmarked for anti-narcotics purposes and "would have been reprogrammed," says Bruce Wharton, to other branches of the armed forces had the congress resisted. Nevertheless, the army got the money, and the opposition walked out in protest. Ernesto Machicao, a congressman who led the fight to block the use of the army, told the *Washington Post,* "People grow coca because it is more profitable than other crops. We start with two battalions, but we do not know where this will end. We never know where the violence ends."

"There is talk, always, of militarization of the drug fight," Burgess says. "Plans are not to do that, not to use the Bolivian army in any kind of operation that affects large populations or towns. Traffickers have been spreading rumors that the army is going to come in and do all kinds of terrible things." That, he repeats, is not the plan—not at the moment, at least. The training, he suggests, is innocuous: jungle survival, small unit tactics, and what he calls constitutional issues, such as human rights and the difference between a soldier and a cop.

Even in hot spots like Santa Ana, the drug police have faced no serious opposition. After all, hundreds of armed men were put into that village and no one was seriously injured, much less killed. Bolivia has no determined rural insurgency, no terrorists like the nihilistic Shining Path rebels in Peru. In fact, a Sendero-like movement seems to run against something fine and gentle in the Bolivian temperament. The way to override these decent impulses, say critics in both Bolivia and the United States, is to start flying soldiers into the Beni.

But since April 1991, a large platoon of U.S. Army Special Forces instructors, bringing several tons of ammunition and equipment, has been teaching two Bolivian army battalions—about 900 men—how to fight the drug war. And when the drug soldiers have been trained, the Red Devils will take them in borrowed Hueys to fight the traffickers, who, faced with losing immense profits from cocaine, will finally begin shooting. There may be another kind of enemy as well. Not trusting the army, some groups of *campesinos* have sworn to arm themselves and fight. If they do, they will keep a sharp ear for the sound of their air force out in the Beni, listening for the heavy rotor beat of troopships, not the time-honored rumble of friendly wings.

Shoot for the Moon

That's what some scientists want. But is our nearest planetary neighbor really worth a return trip?

by Andrew Chaikin

Paintings by Pat Rawlings/SAIC

At the climax of the recent made-for-TV movie *Plymouth*, a deadly solar flare threatens the first settlement on the moon. Huddled with the townspeople in an underground radiation shelter is the show's plucky heroine, physician Addy Matthewson, a widowed mother of four. Her oldest son, Jed, is in mortal peril out on the lunar surface, and she is pregnant with the child of a young helium-3 miner named Gil. Now, with only minutes to go until the flare arrives, Plymouth's wise, homespun mayor, Wendell MacKen-

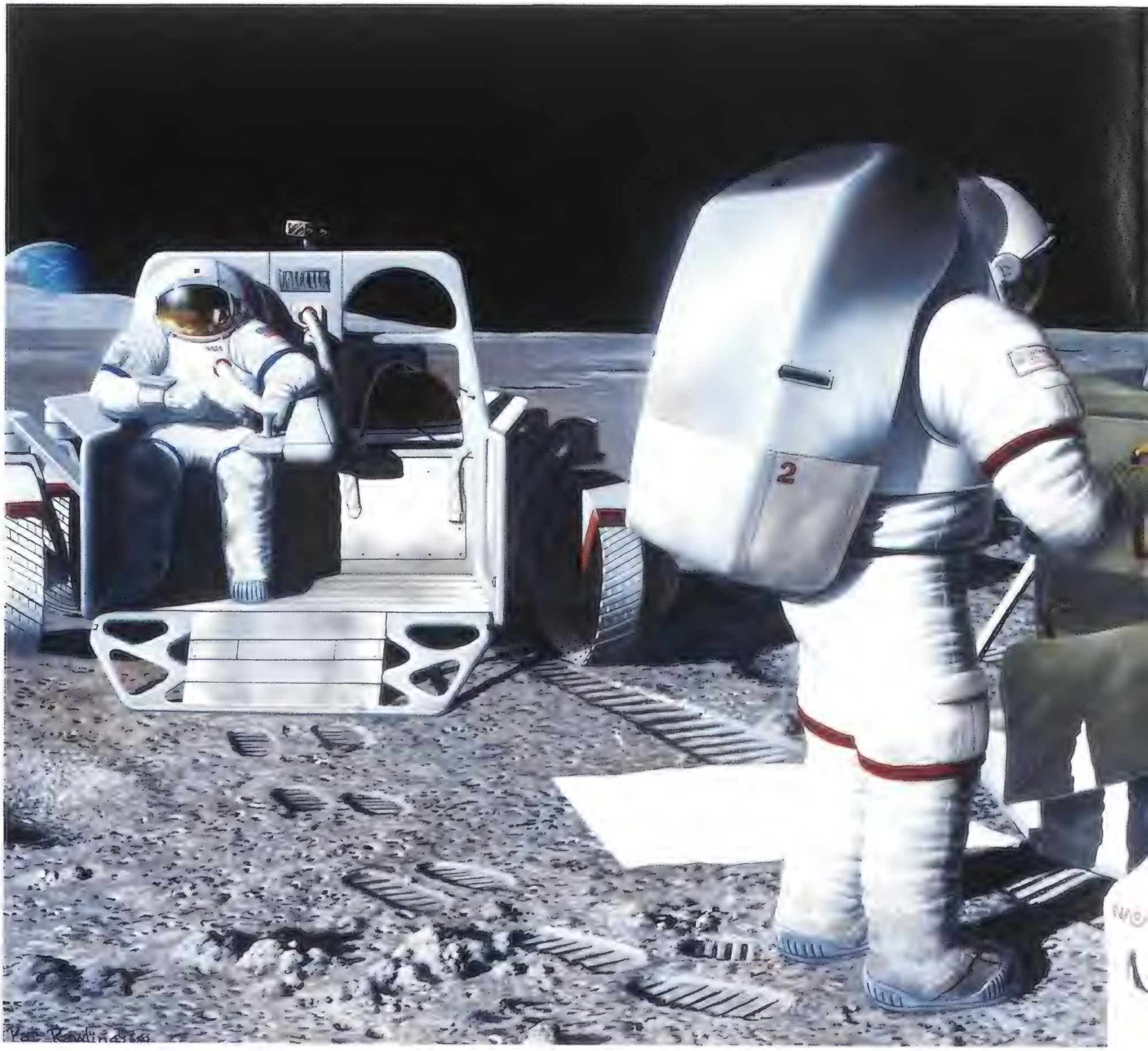
An array of moon-based telescopes, free of a distorting atmosphere, could solve some of astronomy's great mysteries.

zies, turns to Addy and asks plaintively, "Was it wrong to come here?"

Never mind the melodrama. The question is a real one for a cadre of scientists and engineers advocating a real lunar base, and they must answer it in advance: Is it right to go there? When they look at the moon, lunar advocates see an electric power station in the sky, a home for human settlers, and a filling station for Mars voyagers. They see a natural space station and a laboratory for space research. They see lost pages of our own planet's history book waiting to be read. And they see an observing platform from which to plumb the depths of the universe. As far as they're concerned, it's not only right to go there, it's our destiny.

When *Plymouth* aired on ABC last spring, NASA planetary scientist Wendell Mendell watched with interest: he'd been an advisor to the show's producers, who decided to name *Plymouth*'s mayor after him. For nearly a decade Mendell has been the most dedicated moon advocate of all, unofficial leader of the small "Moon Underground," struggling to win his colleagues' enthusiasm when the very mention of a moonbase was met with skepticism at best, ridicule at worst. But Mendell and colleague Michael Duke persisted, becoming the point men for a scattering of return-to-the-moon advocates across the country.

By 1989 Mendell was feeling optimistic. A lunar base was gaining ac-



ceptance within NASA, and there was talk that a presidential directive for a new space effort, including a return to the moon, was in the works. On July 20, when President George Bush listed such a return as one of the primary objectives of his Space Exploration Initiative amid celebrations of the 20th anniversary of the first moon landing, Mendell felt he'd finally achieved what he and Duke had been working so patiently for.

But in the months that followed, NASA faltered. The agency's 90-day report, expected to provide a viable plan for executing the Bush initiative, was widely criticized. The price tag for the 30-year venture—never officially estimated but rumored to be $400 billion—made all but the staunchest proponents blanch. And amid the report's launch timetables and mission descriptions something was missing: a rationale that would help sell the SEI to Congress and the public. The SEI seemed to be a vision not of space exploration but of space hardware.

COURTESY LOCKHEED

Once moon dwellers get settled, they can regularly service observatory equipment.

"In hindsight," Mendell says, "NASA leadership should have asked for more specific guidance before preparing their report. They took the president at his word. I talked to people very high in NASA who really believed that if the president wanted to go to the moon and go to Mars, that he could get the money. I just don't think it works that way."

Enter the Synthesis Group, a 27-member panel created in 1990 at the request of Vice President Dan Quayle to give the vision thing another try. Like previous space study teams, the Synthesis Group had its share of Apollo veterans, including its chairman, astronaut Tom Stafford. But it also had scientists, engineers, military specialists, and academics in disciplines ranging from law to nuclear physics. Perhaps most importantly, it mingled the space program's old corps with younger experts, for whom Apollo had been part of growing up.

Regardless of age, everyone sensed the importance of the task—to find a convincing rationale for the long and expensive effort of human expansion into the solar system. One SG scientist recalls, "The constant feeling among the members during the deliberations was 'If we lose the chance now we've lost it for our generation, and we might as well not do any more.' "

At first, some of the group's senior members resisted the lunar base, fearing it would siphon off resources needed to go to Mars. "Why should we go back?" they said. "We've already been there." To which the younger members responded, "*You've* been there. We haven't."

DAVID NANCE

David Criswell wants to capture solar energy on the moon and beam it back to Earth.

In the end, the Synthesis Group embraced a lunar base for the same reasons apparent to Wernher von Braun in the 1950s and space study panels for nearly four decades since: Mars is too distant and difficult a goal to reach without using the moon as a waypoint. But there was also something new, something crucial to the acceptance of the entire SEI: real economic and environmental benefits. We could go back to the moon to rescue the Earth.

Consider the facts. If the world's population continues to grow at the present rate, the year 2050 will find the planet crowded with 10 billion people. They will face a global environmental catastrophe and an energy crisis of staggering proportions if the current dependence on fossil fuels goes unchecked. "Very few people appreciate what a desperate situation the Earth's in right now," says Max Faget, formerly NASA's chief manned-spacecraft designer and now chairman of the board of the Houston-based spacecraft manufacturing firm Space Industries, who was one of the Synthesis Group's senior advisors.

"We're already well beyond what the biosphere [Earth] can provide," says physicist David Criswell of the University of Houston. "We have to go outside to get something else." That something, Criswell says, is solar energy,

COURTESY EAGLE ENGINEERS

Though settlers will have to grow their own food, they could let robots handle the harvesting.

and he wants to get it on the moon.

"I'm convinced that you can provide virtually all of the world power needs by collecting solar power on the moon, transferring it into microwave beams, and sending it down to the Earth to be used," says Criswell. He formulated the idea of lunar power stations with colleague Robert Waldron in the 1970s, when the space community was abuzz with talk of solar power satellites in Earth orbit. To Criswell, the difficulties of building sunsats—which have to be lightweight, durable enough to survive riding a rocket, and reliable enough to function unattended for decades—would outweigh the benefits (see "300 Billion Watts, 24 Hours a Day," June/July 1990). Instead of going to all that trouble, Criswell says, build solar arrays on the moon, where they could be simple, stationary, and, thanks to the moon's one-sixth gravity, lightweight. Best of all, the metal, glass, and silicon necessary to build them could come from the lunar soil itself.

Time out for a word from an expert on lunar resources, geochemist Larry Haskin of Washington University in St. Louis. Haskin says that the moon's reputation as a barren, desolate world with nothing to offer human settlers is undeserved. "From a chemist's point of view, it's got all the different kinds of materials you might expect to find anywhere," says Haskin, who has been studying lunar resources for over a decade. Heating the moon's soil and mixing the residue with water just might make a splendid concrete. And one of the best lunar construction materials of all could be something more unorthodox: glass. "All you have to do is melt the soil and you can extrude it or cast it or even spin it into fibers, and probably with greater strength than similar products would have on Earth."

Criswell's vision of a lunar base includes automated machinery churning out sheets of glass a fraction of the thickness of this page, ready to be processed into solar cells. Once the energy they capture is converted to microwaves, it can be beamed with pinpoint accuracy to wire-mesh receivers on Earth. Every city would be powered by its own collector, a circular field half a mile in diameter. Simply making the receiver bigger, Criswell says, would increase the energy received.

But there's a catch. Since it takes the moon nearly a month to rotate, sunlight is available for only two weeks, followed by two weeks of darkness. Criswell says

two main power plants, each straddling an edge of the lunar nearside, would provide a continuous flow of power. Even during the long lunar night, mirrors placed in orbit around the moon could feed sunshine to them.

But what about the times when the moon isn't above the horizon at the collecting stations on Earth? No problem, says Criswell. Microwave "mirrors" orbiting high above Earth would redirect energy beams to receiving stations.

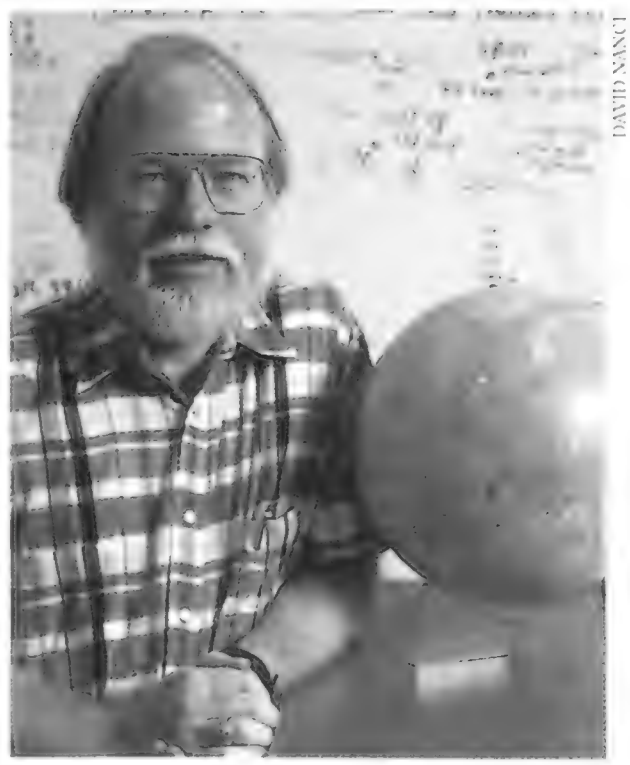
Criswell's timetable begins now, with a decade of research and development, leading up to the first settlers arriving on the moon just after the turn of the century. By the end of the first year, the power stations could be producing 50 billion watts per year, and if more stations were constructed, by the year 2040 we could have a whopping 20 trillion watts—the entire world's energy needs.

How much is all this going to cost? "If I tell you a total it'll scare you," Criswell says. But here's a clue: whatever it costs to set up a permanent lunar outpost, it's only 10 percent of the total Criswell envisions for the entire lunar power effort. That puts the total cost at just shy of a trillion dollars. But Criswell says that after five years of operation, selling power to Earth at a modest 10 cents per kilowatt-hour, the venture would turn a profit. And from then on, he says, the payoff would be enormous.

"There'll be so much money made out of this that you can afford to have an enormous set of space industries on the moon and on Earth and in between. They'll pay for themselves and enable a very high level of world prosperity. And enable a much, much larger space program—far larger than anybody's ever thought about before."

If Criswell's scenario strikes you as a bit fantastic, even utopian, you're not alone. "There's no doubt about it, it's physically within the realm of present-day physics to get power from the moon," says Max Faget. "But there's an awful lot of engineering that has to take place. It's very, very expensive."

One of the engineering hurdles, says



DAVID NANCE

NASA planetary scientist Wendell Mendell has been an outspoken moon advocate for the last decade.

Faget, is the reflectors Criswell envisions in Earth orbit. "They have to be steered while they're moving, and they've got to be very light...to steer something that's got to be almost flat and light—that's damn difficult.

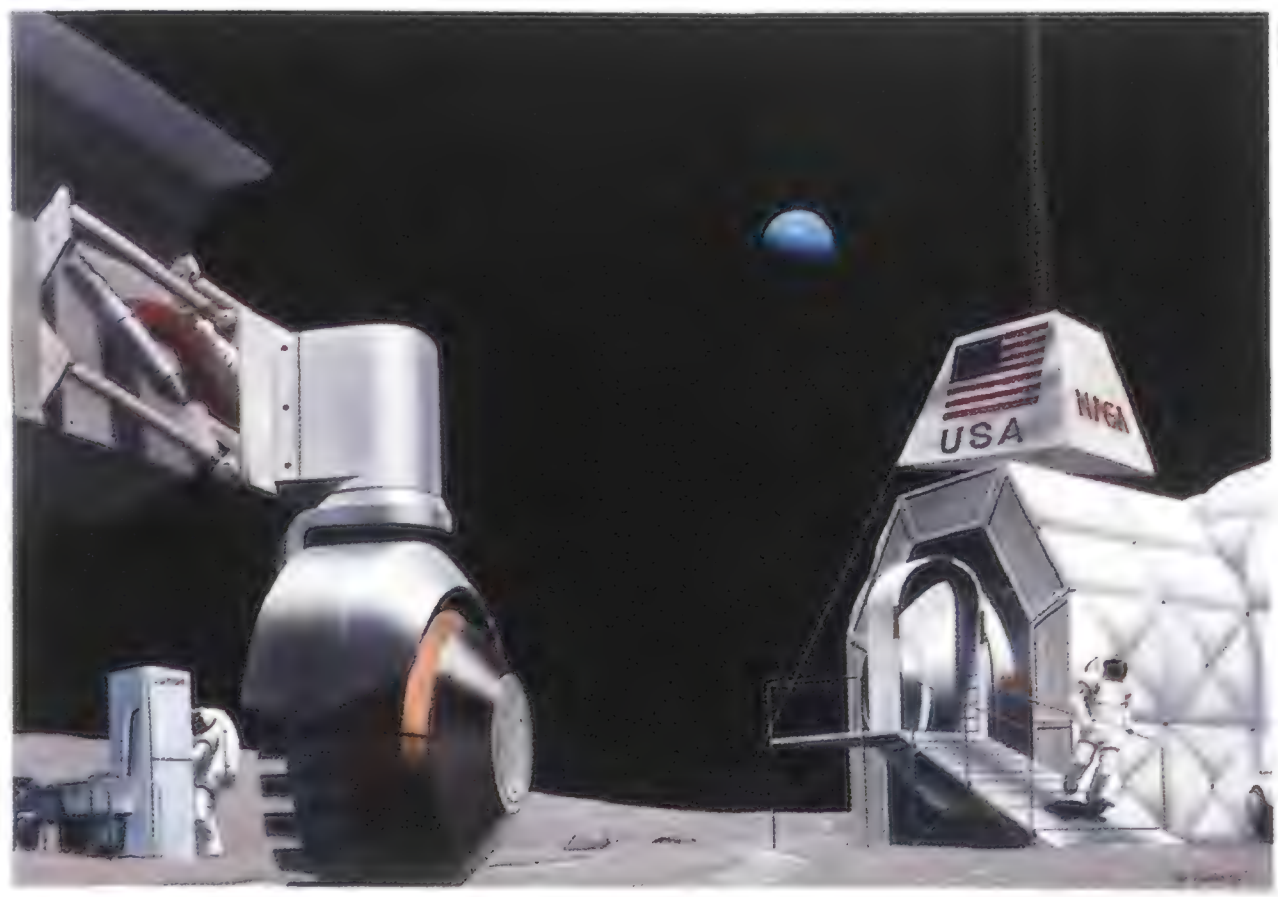
"That's the bad part," Faget says. "The good part is—and he's absolutely right on that—you could literally make billions of dollars per hour if you ever had the plant set up."

The dream of energy from the moon has also caught the attention of the University of Wisconsin's Jerry Kulcinski, who is not a space scientist but a nuclear engineer researching fusion power.

A worldwide effort to create a working fusion reactor is focused on the conventional fusion reaction, in which deuterium atoms fuse with tritium atoms. That process may be the easiest one for scientists to obtain results from, but it has severe drawbacks for the long term: deuterium-tritium fusion releases a shower of neutrons, which severely damage reactor walls, generate significant radioactivity, and waste some 60 percent of the energy produced.

A cleaner, safer alternative is a fusion reaction between deuterium and a rare isotope of helium, known as helium-3. Because that reaction produces hardly any neutrons, a power plant fueled by helium-3 would not only suffer far less damage and give off far less radioactivity, it would yield far more electricity. Fusion scientists would have begun work on a helium-3 reactor long ago had it not been for one problem: on Earth, helium-3 exists only in minute quantities, mainly resulting from the decay of tritium, a component of thermonuclear weapons.

"We've known about this reaction between deuterium and helium-3 for years," Kulcinski says. "But every time we would



NASA

Will NASA be the first to set up shop? Other countries—most notably Japan—may try for the next lunar first.

get beyond the first sentence, people would say 'Yes, but there's no helium-3 around, so why even consider it?' "

That changed in 1986, when scientists at the University of Wisconsin learned that an early '70s analysis of the Apollo lunar samples showed helium-3 to be plentiful in the lunar soil. It is one of an assortment of gases constantly being deposited by the solar wind, a stream of charged particles emanating from the sun. By Kulcinski's calculations, the moon may harbor enough helium-3 to supply ten times the amount of energy produced by all the economically recoverable fossil fuels that have ever been on Earth—enough to meet the planet's energy needs for centuries. And since a metric ton of the gas could provide as much energy as about three billion dollars' worth of coal, it would be worth going all the way to the moon to get it. Says Kulcinski: "This is something for the 21st century that we just have to do."

But even scientists who can vouch for the moon's helium-3 reserves are skeptical. "It's for fusion reactors, right?" says planetary scientist Alan Stern of the Southwest Research Institute in San Antonio, Texas. "*What* fusion reactors?"

Lunar settlers will find the moon's crater-covered surface a most exotic playground (above).

Jerry Kulcinski (below) wants to mine the moon's supply of helium-3 for use in Earth-based fusion reactors.

COURTESY JERRY KULCINSKI

"People who are not in the fusion community don't realize how fast this field is moving," Kulcinski responds, noting that a conventional fusion reactor may be operating by the turn of the century. A helium-3 plant would be much tougher to perfect because it requires even higher temperatures than the 100 million degrees needed for deuterium-tritium fusion. But Kulcinski has no doubts it could be done; a 300-megawatt helium-3 power plant utilizing the minute supply of helium-3 on Earth, he says, could be on line by 2015. By that time, the first settlers might be arriving at the moon—and their mission could be to get more. If so, they may use a roving helium-3 miner much like the one being designed by Kulcinski's group and the San Francisco-based construction firm Bechtel. Roughly the size of a Greyhound bus, it would creep over the surface like a river boat in reverse, its bucket-wheel scooping up lunar dust and feeding it inside where it would be heated to release the precious helium-3.

However valuable helium-3 proves on Earth, mining it will yield a cornucopia for lunar settlers. For each ton of helium-3 taken from the lunar soil, the miners could also extract 3,300 tons of water, 6,100 tons of hydrogen, 1,600 tons of methane, and other gases valuable for survival and industry. In time, helium-3 mining could sustain not only the energy needs of Earth but the survival of an industrial community on the moon. Because solar wind gases also include nitrogen and carbon, the lunar soil could even provide settlers with nourishment. "It's just a matter of chemical synthesis," Larry Haskin says. Once nitrogen, carbon, and other building blocks are harvested from the soil, "you can turn it over to biological entities to do the rest. That's how we do chemical synthesis on Earth."

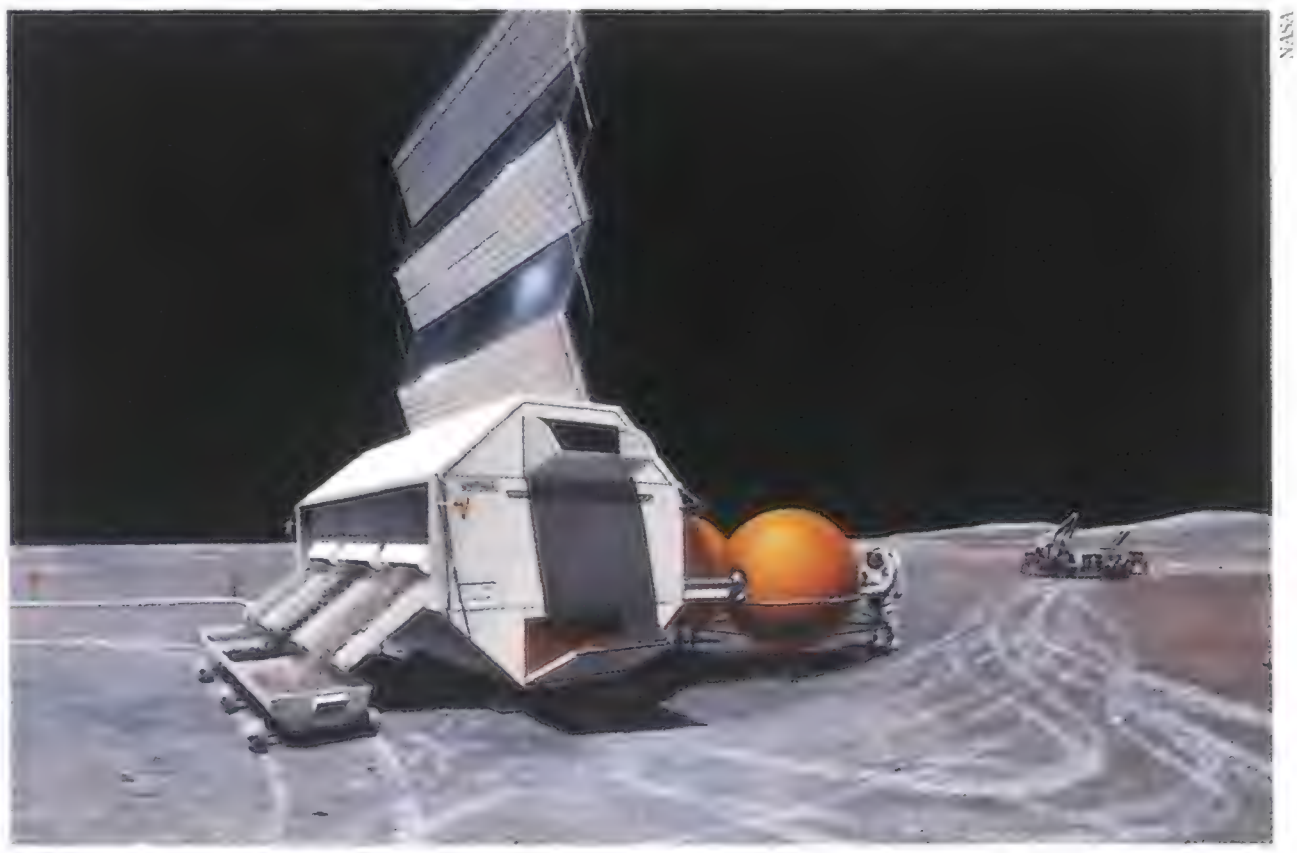
The vision of an industrialized moon, however, does not entirely mesh with the better known one of a world ripe for geological exploration. "We have an environment that is as delicate as the most fragile cave on Earth," says Brown University geologist Peter Schultz. He fears that too much human activity too soon might erase some of the moon's eons-old history. "If we really want to exploit the moon," he says, "then I think the first priority is to understand it."

Perhaps the most fragile treasure awaiting lunar scientists is the moon's atmosphere, a wispy envelope whose surface pressure is only one ten-*trillionth* that on Earth. It includes gases that have escaped from deep within the moon, undoubtedly bearing clues to its evolution. Human activities could make it impossible to detect them. The lunar atmosphere is so thin, says Alan Stern, that the rocket exhaust from even a single Apollo landing caused temporary massive pollution, leading Stern to conclude that we should study the lunar envelope before trampling it. But he adds: "I do not want your readers to get the impression that perturbing or destroying the lunar atmosphere would be the end of lunar science."

Whatever the fate of the moon's atmosphere, its surface wouldn't likely suffer appreciable harm from human activities; even helium-3 mining would disturb only the uppermost yard of topsoil, and it would take decades to affect a significant area of the moon. Mining the Sea of Tranquility, roughly the size of Wisconsin, would meet the United States' energy needs for four centuries.

Undoubtedly the first lunar settlers will include geologists eager to probe the mysteries left unsolved by the Apollo missions. Scientists still do not know key details of the moon's evolution: how its core, mantle, and crust formed, when its fiery outpourings of lava began, when the moon went cold, and—the most basic question of all—where the moon came from. All of these questions will be on the minds of any geologists who get the chance to venture out among the moon's craters and boulders, canyons and mountains. Unlike their Apollo predecessors, they won't be forced to rush from one geological bonanza to another, slaves to limited oxygen supplies and the ticking of the mission clock. For the first time, they'll be able to do what field geologists do on Earth: spend as much time at a discovery as necessary. In the process, they will probe the earliest history of our own planet, and even the sun, since the solar wind gases present in lunar soil constitute a record of the sun's output through the millennia. One scientist likens the moon to "a solar telescope with a tape recorder."

The moon is equally alluring to astronomers. The late Harlan Smith, a University of Texas astronomer, said that once settlers set up shop, the moon will supplant Earth as the prime locale for surveying the heavens. Even aside from its flawed mirror, the $1.5 billion Hubble Space Telescope demonstrates the difficulties of using telescopes in Earth orbit, where they must remain pointed at distant stars and galaxies while zipping around the globe at 17,000 mph. A telescope on the moon, being free of Earth's blurry atmosphere, would have all of the Hubble's advantages but none of the disadvantages.



NASA

Chock full of riches, lunar soil can be mined and processed into water, fuel, and construction materials.

The telescopes Smith dreamed of are huge arrays of mirrors, called interferometers, that would act in concert to yield fantastic resolving power—up to a million times better than Earth-based telescopes usually achieve today. On the airless moon they would partake of the entire electromagnetic spectrum, from radio waves to gamma-rays.

Smith called them nirvana telescopes. "If you had one of these telescopes on the moon," he said, "you could not only read a newspaper on the Earth, but you could study the fine structure of the type in each character. Once we find planets around other nearby stars, we could even see surface detail on those planets with such a telescope. Or we could look down into the hearts of

Geologists hope that the secret of the moon's origin lies cloaked within the folds of its crust.

quasars and look at the regions around the black holes that are there. Who knows? I mean, every time you make a gain of *one* order of magnitude with our instrumentation, we've always found new and exciting and important things. To make *five or six* orders-of-magnitude gain—that's another universe."

It's hard to listen to all these moon advocates without wondering whether any of their predictions is really going to happen. To paraphrase Lao-tzu, a journey of 240,000 miles begins with a single step—in this case, the research and development programs necessary to turn moon dreams into reality. Larry Haskin, for example, would like to see funding for the technology to harvest lunar resources. Today, he says, if you tried to tell most engineers to build with glass instead of aluminum, "they're going to freak out. They don't have a clue how to deal with that.

"The kinds of things I work on...nobody's funding," says Haskin. "Because nobody has the money. A good bit of the leadership in NASA thinks it's silly to work on that kind of stuff." Haskin senses that the assumption at the space agency is that if an idea exists on paper, it won't be hard to turn it into reality. He says the response he gets from NASA officials is, "We don't want to work on all this stuff now. Come and talk to me five years before we go."

Given that kind of resistance, what assurance is there that the Synthesis Group's plan will have any more impact than its predecessors', the 1986 Report of the National Commission on Space and the Ride commission report a year later? The members have returned to their organizations to keep the message alive. "It's the only hope," says one Synthesis Group member of the moon-base goal. "The truth ultimately will out. It is the right thing to do. And it is the future of the space program."

That's a message many feel needs to get through to both NASA and Congress, but the agency seems preoccupied with its efforts to build space station Freedom. Having narrowly escaped cancellation during Congressional budget deliberations last spring, the station is still being criticized as ill-suited to scientific research, overpriced, and way behind schedule.

"NASA has a tremendous credibility problem," Wendell Mendell says. "If they want to treat the Space Exploration Initiative as a way to gain a commitment from Congress to fund NASA for these visionary programs, they damn well better have a track record of spending the money wisely and efficiently and in

a way that people can see the benefits. And to my mind the space station program is the antithesis of that."

NASA seems so absorbed in keeping the space station alive and the shuttle flying that it has little energy left to pursue anything else. Says one SG member, "In some ways, [the Department of] Energy was hotter for SEI than NASA [was]. We were incredulous. It was outrageous." In the face of a grand opportunity, NASA seems to be going through an identity crisis. "I think that NASA still does not have a view of itself as being a leader in the Space Exploration Initiative," says a scientist in NASA's office of exploration. "It is not NASA that is providing a vision of the future. NASA is sort of waiting around for somebody to tell it what to do."

In one sense, the lunar base is no closer to reality than it was when Mendell began his advocacy in the early 1980s. It is still not a real, funded program with a timetable. No metal has been cut, no potential launch dates selected. And yet, Mendell says, things have improved. "Right now, it is actually legitimate to think about lunar bases within the NASA system. And in 1983 it was not. That's a major change in mindset—that it's actually okay to talk about it."

The change is just as apparent outside NASA. Mendell says he can now pick up the phone and call people across the country—at universities and think tanks, at construction engineering firms, at other government agencies—and start a conversation about lunar bases without first having to launch into a long explanation of what he is talking about. Mendell says moon advocates are like dormant seeds that will blossom when money becomes available.

When will that day come? Mendell believes that as worthy as it is to think of solving the world's energy problems on the moon, it will not be the reason that actually motivates us to go back. "Dave Criswell will argue you into the dirt that it makes pure economic sense to build the lunar power station and take the power source off of the Earth," he says. "[But] people will never arrive at that solution until there is a broader context in which you can develop the lunar power station.... They'll always have that difficulty in advancing that argument until there is a widespread belief that going into space is part of manifest destiny."

If Mendell is right, then what all of this is really about is not a decision to exploit the moon or even to explore it, but to cut the cord with Earth once and for all. We will have to come to the same conclusion Addy reaches in the final minutes of *Plymouth*, after she has decided to have her baby on the moon and the townspeople have decided to remain there forever: "We decided there was no turning back."

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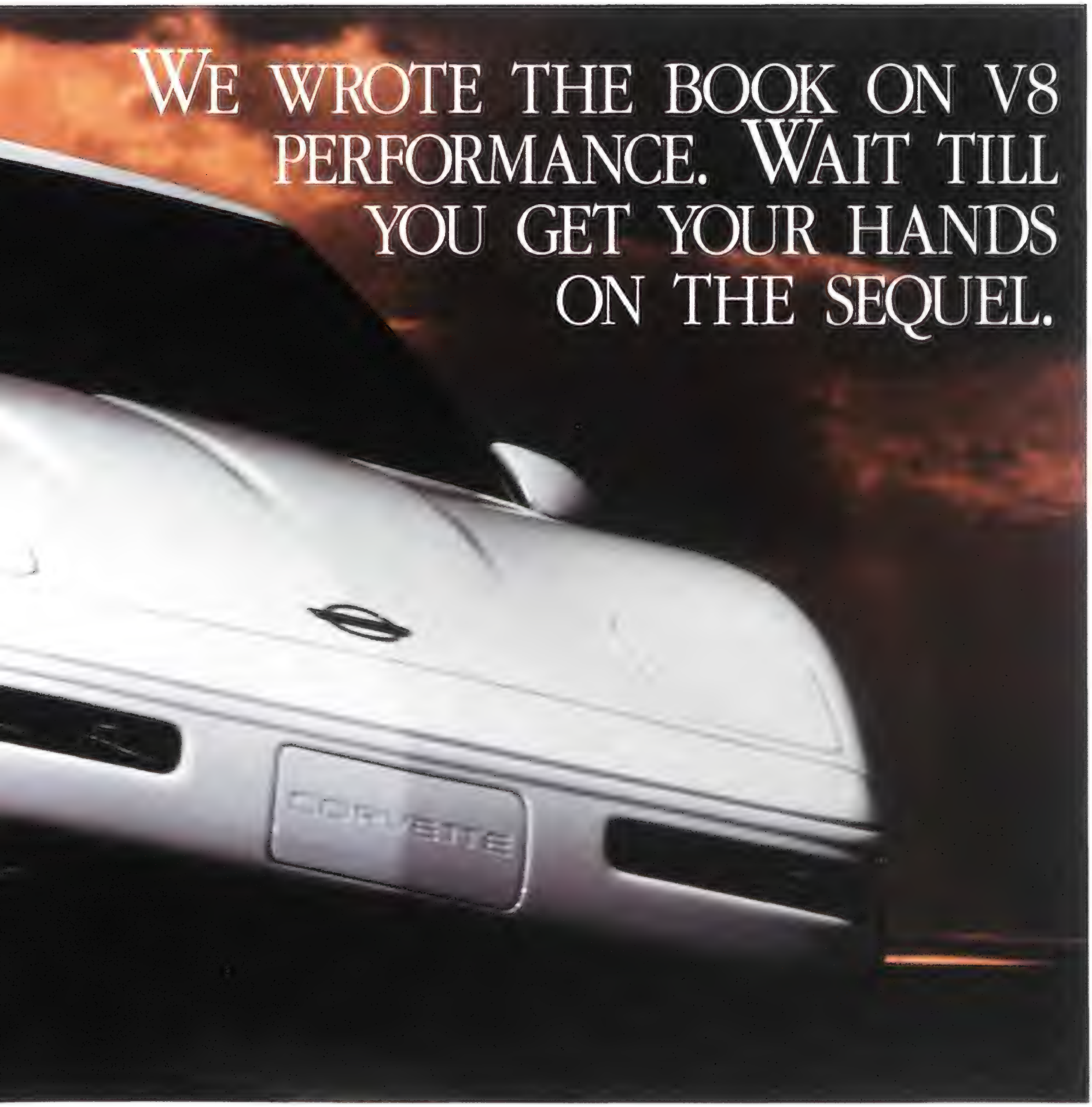

application of power to the rear wheels, providing optimum grip in all traction conditions. ♦ Test-drive the 1992 Corvette LT1. Cover to cover, it's the best 'Vette yet.

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TROUBLE IN PARADISE

They entered the holistic mini-world of Biosphere 2 in search of great science. Did they leave scientific traditions behind?

Story and photographs by Roger H. Ressmeyer, Starlight

On September 26, 1991, four men, four women, and 3,800 animal and plant species assembled in a vast glass building in the Arizona desert and set about reinventing the world. For two years, according to the plan, those men, women, pigs, goats, hummingbirds, lizards, termites, earthworms, lemon trees, rice paddies, and other forms of life will live sealed off from the surrounding air and climate and ecology—sealed off, in fact, from the entire planet Earth. The only things that will enter their home will be information and energy.

This latter-day Noah's Ark, complete with man-made rainforest, ocean, and desert, is called Biosphere 2, and the research that will be conducted within its three acres, says Biosphere public affairs director Kathleen Dyhr, will be applied to the development of a space station or a permanent base on the moon or Mars. It is also designed to produce commercial spinoffs, such as filtering and recycling systems, that will help remedy ecological problems here on Earth ("Biosphere 1," in the parlance of the project). Biosphere 2 may be "the most exciting scientific project to be undertaken in the U.S. since President Kennedy launched us toward the moon," reported the science magazine *Discover,* and other press reports have been similarly enthusiastic.

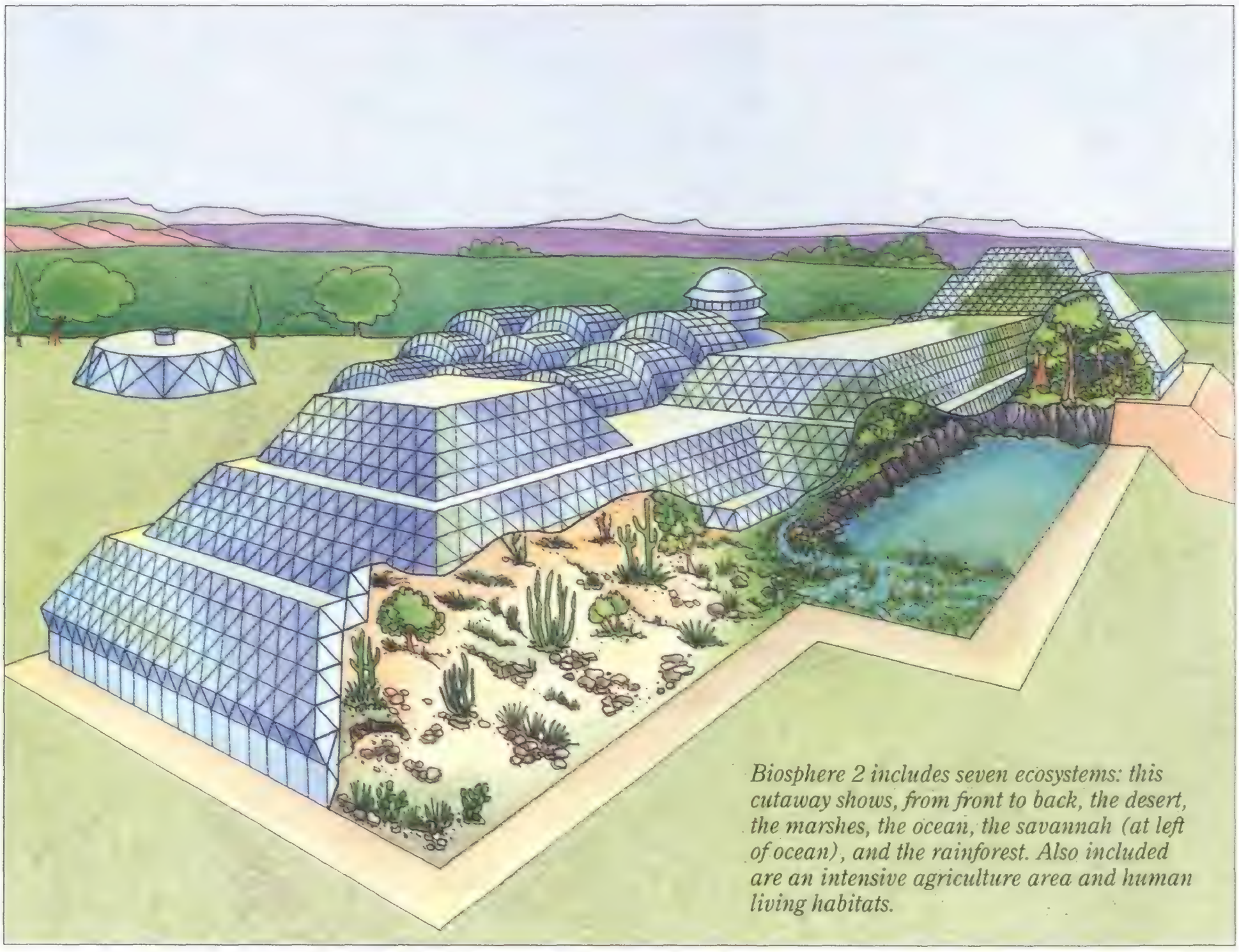
The men and women of Biosphere 2 have a flair for the dramatic that some academic scientists find unsettling.

Critics of the project, on the other hand, call it gimmicky and self-indulgent, a plan of dubious scientific merit masterminded by a cult-like clique.

Many of the people behind Biosphere 2 are not conventionally trained in the sciences. Some of them go back 20 years or more, when they belonged to an experimental theater group living in a New Mexico commune known as Synergia Ranch. Sociologist Laurence Veysey, now retired from the University of California at Santa Cruz, spent five weeks with that group in 1971, and his book *The Communal Experience* documents the commune's preoccupations and interrelationships. Especially harrowing are Veysey's observations of Synergia leader John Allen, an ex-metallurgist who sometimes went by the name "Johnny Dolphin" and was given to apocalyptic preachings and volcanic rages, particularly at the dinner table. Today, Veysey characterizes the Synergia group as "Jonestown-like."

In the 1970s Allen hooked up with Edward Perry Bass, scion of a wealthy Texas oil family, and, according to an investigative piece by the *Village Voice,* persuaded the young heir to join the group and ultimately to underwrite a series of projects with ecological themes. One was the formation of something called the London Institute of Ecotechnics, an unaccredited entity that went on to grant "degrees" to several group members. One recipient was Synergia resident Margret Augustine; today, Augustine is president and chief executive officer of Space Biospheres Ventures, the private outfit that planned and now controls Biosphere 2. John Allen is SBV's director of research and development.

It is mostly Bass money—over $100 million—that is funding Biosphere, not only the construction but the participation of some outside researchers. Scientists from the University of Arizona, the Royal Botanic Gardens, Yale University, and the U.S. Geological Survey all signed on, as did two researchers from the Smithsonian Institution: as-



Biosphere 2 includes seven ecosystems: this cutaway shows, from front to back, the desert, the marshes, the ocean, the savannah (at left of ocean), and the rainforest. Also included are an intensive agriculture area and human living habitats.

sistant secretary for external affairs Thomas Lovejoy, who sits on Biosphere's review board, and marine systems lab director Walter Adey, who designed Biosphere's aquatic systems. According to the *Voice,* the Biospherians are recruiting legitimate research organizations less for the expertise they bring than for the veneer of credibility they confer.

The week before Biosphere 2 was sealed up, Ed Bass finally decided to break his long-standing policy against talking with the press and address some of these criticisms. "There was a NASA cult that got us to the moon in the '60s," he told the *New York Times* in response to the cult question. "...I would say NASA's effort that got us on the moon and Biosphere 2 have a lot in common." Bass also defended John Allen, calling him "a fine human being" and "an exceptional intellect."

As for the criticism of the Biospherians' scientific training, the Smithsonian's Lovejoy says, "You don't have to have a Ph.D. to count plants. As long as the data is recorded and stored in a database, I think things can be learned." He adds: "People say they don't know what they're doing. Well, no one ever *built* a rainforest before. What they did was go to the people who really know rainforests and get their help, down to the level of deciding which species to pick."

Kathy Dyhr, for her part, responds to the *Voice* allegations by saying: "It's unfortunate that scandal and gossip take precedence over the really substantial issues [like the] level of pollution in Mexico City.... John [Allen] is the director of research and development, and what he did 20 years ago, frankly I don't know because I didn't know him 20 years ago, and it was the 1960s.... I think that most of the stuff as far as John is concerned is just personal gossip and I think it's irrelevant to the project.... Human beings are really great at making deserts out of rainforests, but nobody has ever tried to do the reverse."

I never mentioned Dyhr's remarks when I talked to Paul Buchanan, Kennedy Space Center's director of biomedical operations and research, yet he ended up using precisely the same imagery in spelling out his doubts about Biosphere: "I'll be interested," he said, "in finding out whether they will be able to grow what they want to grow, eat what they want to eat, and still come

out with something other than a total desert when it's all over."

A closer look at NASA's future life support needs provides some insight into the Biosphere project. From the very beginning of manned spaceflight, life support systems have been of the machine-driven, "open loop" variety. In space an astronaut consumes about four pounds of food, five pounds of water, and 11 pounds of air each day, and though the air is chemically scrubbed and some of the perspired moisture is recovered, basically the necessities of life are used up and the by-products discarded as waste.

It's a system in desperate need of overhauling: to keep just a low-Earth-orbit mission supplied in essentials using today's launch technology (the shuttle) would cost over $58 million per year per astronaut—$111 a minute. More sobering still is the prospect of a resupply mission failing, especially one deployed to aid a year-long trip to Mars.

So at the same time that Biosphere is beginning its experiment in closed-loop living, three NASA centers, as well as several aerospace contractors, are expanding their research into similar areas. NASA, in fact, espouses the same general plan as the Biospherians—using a balance of organisms to recycle air and water, reprocess human and

The Biospherian glazing process (right) "will be one of our first important technologies," says Margret Augustine. Some question whether the miles of seams will prove truly airtight.

plant waste, and grow a balanced diet of fresh foods that will support every life-form in the system. (Of course, NASA being NASA, the agency has come up with an acronym for its bio-regenerative life support program: CELSS, for Controlled Ecological Life Support System.) NASA scientists even have their own version of Biosphere in the works: the Human Rated Test Facility, a CELSS system for two to four people scheduled to be operational in about five years.

But NASA's research methodology is diametrically opposed to the approach the Biospherians are taking. Biosphere kicked off with close to 4,000 species distributed throughout seven simulated biomes—ecosystems such as a desert, savannah, rainforest, and ocean; in contrast, NASA currently operates two sealed plant growth chambers, 20 and 26 feet tall, and hopes to build up to a combination of perhaps 13 plant species in each. The idea is that this modest selection will be sufficient to provide a varied diet with all necessary nutrients, as well as replace the carbon dioxide given off as human waste with oxygen needed for human respiration.

Biosphere's research protocol does not include a control—a setup in which every detail of the experiment is duplicated except for the crucial variable being studied. For Biosphere, such a control might be an identical grouping of plants and animals that is kept in a

At 67, physician Roy Walford (above) is the oldest crew member to embark on a two-year stint in the three-acre glass complex (right).

NASA conducts closed-loop research in sealed plant chambers; William Knott (standing) directs the one at Kennedy Space Center.

vented greenhouse, or a greenhouse that is impermeable to certain kinds of ultraviolet light. Any differences between the two setups at the end of the study could then be attributed to the variable: ambient air, ultraviolet light, or whatever else was controlled.

"It isn't the kind of approach that I would undertake," NASA's Paul Buchanan says of Biosphere. "I find it difficult to believe that I could understand what the interactive mechanisms are. I think it would take a God of all biology to understand that." NASA planetary scientist Wendell Mendell has some of the same impressions of the project, though he couches them a bit more charitably: "In a scientific endeavor you try to do something which you can understand and which can be reproduced by other people in order to confirm whatever conclusions you reach," he says. "They have their eye on the horizon, and because they are not steeped in scientific culture, they do things which are 'non-scientific.' It's a methodology which doesn't lend itself to advancing human knowledge in the most general sense."

Kathy Dyhr answered this criticism with a lengthy discussion about how Earth has been treated to a huge uncontrolled experiment by a polluting, tree-murdering overpopulation of humanity. "I don't think we are condemned to eternal ignorance because it is difficult to do statistical studies at Biosphere 2," she concluded. When the same criticism was posed to the Smithsonian's Thomas Lovejoy, who sits on Biosphere's review board, he responded: "Well, more than half of science has no control...in many, many instances there is no choice." He suggested that the experimental variables can be studied serially—that once the first two-year stint is over, for instance, the Biospherians could repeat the experiment but double the carbon dioxide level, thereby obtaining a second set of data that can be compared with the first.

Though Buchanan and Mendell were willing to air their observations of Biosphere on the record, other scientists were reluctant, even fearful. One expert on the human factors of spaceflight explained, "NASA is trying to disassociate itself from the Biosphere project. Scientists who criticize the methodology at Biosphere have been threatened

with lawsuits. It's just too risky to speak out. Therefore I have no comment, except that you should read the story in the *Village Voice.*" The scientist was referring to the report that outside consultants who had left the project and later criticized it were threatened with lawsuits and asked to sign recantations. One subsequently told *Voice* reporter Marc Cooper, "I'm a college professor with a limited income. I can't afford to talk to the press."

"That is not the way credible scientists should treat each other," Buchanan says of Biosphere's fiercely protective ways. The project managers, he goes on to recount, are claiming credit for technology they didn't truly invent, such as the rubber lungs that are used to equalize pressure inside the structure when the temperature changes. "The Johnson Space Center is doing CELSS work using lunar soil simulants as a substrate," he says. "They needed a pressure relief system so they built a lung—an old concept that goes back 30 or 40 years. When they found out about it at Biosphere, Margret Augustine sent a letter to JSC's director threatening a lawsuit for patent infringement.

"There's an entrepreneurial character to this thing that turns off a lot of the scientific community," Buchanan adds, "a hucksterism I'm not used to seeing in a truly scientific endeavor."

"I don't think it's malicious," says NASA's Wendell Mendell, "but I think that they are clever and cunning in their approach in a sort of native intelligence way, and they don't really appreciate all the rules, customs, and finesse that people who are brought up inside the scientific professional culture understand. It's the same kind of thing I encounter in bright, young, enthusiastic students...who use things without paying a lot of attention to credit. I think that their intentions are by and large honorable, but I had the distinct feeling when I first met them in 1986 that everybody had just happened to be around the same table in a bar a few years earlier and now they were all in charge of things."

My own uncomfortable experience with the planners of Biosphere illustrates some of their odder notions about the control of information. As a freelance photographer on assignment for *National Geographic* and *Life* magazines, I made three visits to the giant greenhouse. Upon arrival, I was asked to sign a severely worded agreement granting Space Biospheres Ventures control of all photographs made on the premises, "so that they won't be used to illustrate articles by writers who haven't visited the site," according to Kathy Dyhr. The contract also gave SBV the right to use the pictures in any way it saw fit, except for actually selling or marketing them. The agreement in effect would have transformed me into an unpaid employee for Biosphere. In 15 years of covering science and technology stories as a photographer for national magazines, I had never before been asked to sign such a contract.

The agreement also ceded SBV the right to use the entire magazine article "for its purposes," except for actually selling it in a reprinted form. During my last trip for *National Geographic* magazine, I pointed out that I could not sign such an agreement because I didn't have the authority; in response, Margret Augustine chewed me out for my lack of cooperation and barred me from entering Biosphere. Finally, after I had spent almost four days waiting in the administration building, the magazine told SBV it would have to cancel its coverage. Augustine abruptly agreed to reword her agreement, but it was too late. The *National Geographic* dropped its story plans anyway. (Today, Biosphere personnel say they no longer ask such concessions of media visitors.)

SBV has also shown a striking stubbornness in its dealings with the scientific community. David Stumpf, one of the University of Arizona scientists who was threatened with a lawsuit after criticizing the project, told the *Village Voice* that once, while giving a presentation to the Biospherians, "John Allen vigorously interrupted, telling me, 'I don't know why you're approaching the science this way...everything will balance properly.' It was apparent that conflicts between our traditional approach and the Biosphere 2 New Age approach was going to be a problem."

On the other hand, Thomas Lovejoy of the Smithsonian has no complaints about the Biosphere staff's cooperative

PR director Kathy Dyhr helped care for the hundreds of plants that eventually filled Biosphere 2.

spirit. "You can tell if people are listening or just going through the motions," he says, and in his experience, the Biospherians listen. And as for the charge that the Biospherians are using the Smithsonian name to cloak their undertaking in the mantle of scientific respectability, Lovejoy says, "The important thing is for people to understand that what Walter Adey did was in his capacity as a marine ecologist, and what I'm doing is as an ecologist. Neither implies an institutional blessing."

Just how valuable will this complex and costly replica of seven Earthly ecosystems prove to be? Ironically, the holistic approach the Biospherians are taking is deemed likely to result in the death of many of their carefully selected species. "Everything simplifies when you close up a microcosm," says Steve Schwartzkopf, Lockheed project leader for the CELSS effort. "From a holistic point of view, [Biosphere's approach] is the best way to come up with an operational ecosystem: you put everything you might want together and let the species die off that are going to die off.... But statistically, with this approach you're going to have to run an awful lot of time-consuming experiments to come up with a good mixture of species to achieve human life support. That's why at Lockheed we're approaching it from more of a reductionist perspective, deciding what species we want to include for convenience in order to lessen the complexity of the systems engineering job."

The biggest scientific question of all about Biosphere 2—the question on which all others depend—is whether a 3.15-acre glass house, with 50 miles of glazing seams between the windows and space frame, plus another 12 miles of welded seams, can be made truly airtight. Says William Knott, director of the CELSS plant chamber at the Kennedy Space Center, "If you're looking at the buildup of toxic gases, you've got to have a low leak rate. If you've got a large leak rate, then obviously there are restrictions on what scientific questions you can ask." So how tightly will leakage be controlled? In his book *Biosphere 2: The Human Experiment,* John Allen says that according to a Biosphere engineer, the leak rate will be "just over three percent a year," though "improved quality control in application" could lower the rate to one percent, meaning that "over the course of a century the air inside Biosphere 2 would change-over only once."

"That's an unbelievably small amount of leakage," says Paul Buchanan. "I

Abigail Alling prepares for a dive in Biosphere's ocean (above). The greenhouse also boasts massive man-made rock formations (right).

don't see how they'll ever get down to that kind of a leak rate with all of those glass and steel seams." Buchanan points out that Kennedy's sealed plant chamber currently leaks about five to eight percent in a single day.

Addressing this structural challenge at a recent lecture, Margret Augustine recounted, "We developed methods where we would be able to vacuum-test [the seams] in the factory and then later come back and vacuum-test...all the way along the whole structure, more than once." According to Kathy Dyhr, "The way we've set this up, the atmosphere is the most sensitive part of the experiment. But a 10 percent or even 20 percent leak rate per year is still acceptable for our experimental purposes." But even that estimate seems optimistic: NASA's tightest spacecraft, the shuttles *Discovery* and *Atlantis,* leak about 340 percent a year.

To get a better understanding of leak rates, I called Johnson Space Center engineer Lewis O. Casey, responsible for the largest vacuum chamber in the unclassified world. Known as Chamber A, it measures 90 feet tall and 55 feet in diameter and was used to qualify the Apollo command, service, and lunar modules all at the same time. Casey explained that it is even more difficult to seal an unpressurized chamber such as Biosphere than it is to seal a vacuum chamber, in which the force of the vacuum maintains pressure on the O rings sealing the doors. "Anybody trying to seal against barometric changes and the velocity of wind has an even greater challenge because they have to build in that kind of a sealing force with gaskets or sealant," he said. "The sealing material has to stay resilient with time and has to accommodate all the thermal changes of day and night. They're going to be leaking all the time, and because they can't freeze the dynamics of small pressure changes, it's going to be hard to leak-check or even to determine the leak rate so you can factor it into your experimental results. I'm hard pressed to explain how they're going to do their job."

"What it most certainly will be is interesting," says Paul Buchanan. "I'm watching it very carefully. But whether or not it's worth all the money they're spending on it, I frankly doubt it. I can almost guarantee that it won't ever get anybody a Nobel prize. But at the same time, it will develop some interesting questions that graduate students will be addressing at a more detailed level for decades to come."

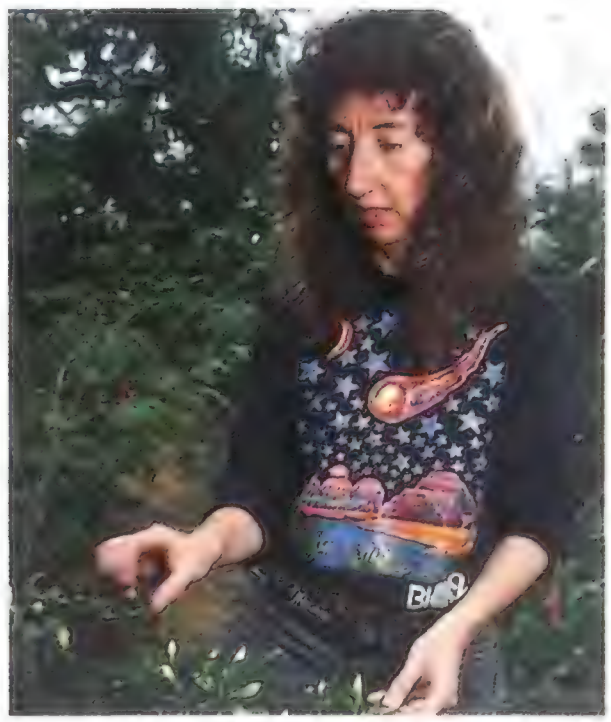
Arnauld E. Nicogossian, who directs NASA's life sciences division and heads all of the bio-regenerative life support projects at NASA centers, suggests that Biosphere 2 will save NASA tens of millions of dollars. "I am very happy with what they are doing because one element of experimentation is discovering the failure points," he explains. "If you put a system [like Biosphere] together, you will find out where that system will fail. In effect, you identify the areas where more research is needed, and you learn how to spend your money more effectively."

All true—provided the Biospherians are willing to share their results. So far,

notes Don Henninger, chief scientist for regenerative life support at the Johnson Space Center, "we in the outside scientific community have very little information to go on, so it's very difficult to draw any conclusions." Lovejoy recounts that at his last meeting with the Biospherians, he "got after them" about not communicating enough with the outside scientific community and advised them to prepare a paper about their work for submission to a widely read scientific journal. They followed his suggestion. Says Lovejoy, "I know that what sometimes happens is you get a [scientific] project going off in the corner somewhere, and it's different, and you get swept up in what you're doing" and neglect to communicate with others. Perhaps because he works in the aerospace industry, Steve Schwartzkopf has a sympathetic take on the Biospherians' wariness: "If you put yourself in their shoes and look at it from the perspective of making a return on your investment," he says, "you don't want to give away your secrets."

And that investment is mammoth, especially compared to NASA's: "Of all the technologies involved in a Mars spacecraft," says Apollo 11 astronaut Michael Collins, "the biological life support system is the long pole in the tent—the one that NASA is farthest behind on—and it may very well slow the project down in the end. To take all the horrible products that our bodies get rid of and recycle them into a pure and palatable form is a horrendous task that NASA is very slow to approach. It's not in NASA's normal line of work—rather than shiny sliding metal parts, it's slimy goo and horrible odors, not the sort of thing that lends itself to keen engineering analysis." Currently, the agency is spending $5 million over the fiscal year on plant growth and waste reprocessing experiments.

The question, then, is which group will produce the most usable knowledge for the money: the lavishly funded but proprietary venture, or the modestly funded but publicly accountable government agency. In any event, the Biospherians, capitalized as they are by one of their own, are under no obligation to share their work with anyone. As Dyhr puts it in a moment of startling candor, "If Ed Bass wants to spend a



Crew member Mark Van Thillo adjusts environmental sensors in the savannah (left), while over in the rainforest, Linda Leigh tends to the plants.

hundred thousand dollars on cotton candy, that's his business."

We can hope, nonetheless, that Bass and his Biospherians will resist the self-indulgence and greed that such a scenario suggests. Bio-regenerative research and technology, as Schwartzkopf points out, is every bit as necessary on Earth as it is in space. "In space we have to recycle every scrap of waste material, and that research has a direct spinoff to Earth's landfill problems," he says. "For space, we're looking at new methods of cleaning toxics out of water using bacterial beds. Those techniques can be used to eliminate water pollution on Earth. For a Mars greenhouse, we're looking for plants that can handle low temperatures, drought, and increased ultraviolet radiation. We may end up with crops that are better adapted to the conditions that they will have to face here on Earth in the next 20 years, if the greenhouse effect is real."

Wendell Mendell likens Biosphere 2 to Lewis and Clark's expansion of the American frontier: "It's more like an exploration than a scientific study," he says. "You've got to give them credit.... It may not be a Michelangelo piece, but it certainly is a wonderful adventure which will have useful results on a number of levels. And one of those levels is probably science." ✈


HILTON
NASA

The Biggest Little Airplanes In Texas

The models at last summer's Rally of Giants give new meaning to the word "upscale."

by Ed Regis

Photographs by David Nance

I'm standing on the flightline of the International Miniature Aircraft Association's 11th annual fly-in, rally, and all-around fun fest. Since it's the International *Miniature* Aircraft Association you might reasonably expect to find an array of little airplanes: minuscule scale models that fit in your pocket, thimble-sized aircraft built with a watchmaker's tools and tweezers, whose paint schemes had to be applied with Q-tips.

But no: airplanes at this fly-in have a minimum wingspan of 60 inches for biplanes, 80 inches for single-engine monoplanes. On the hot asphalt in front of me is a C-119 Flying Boxcar, both engines turning. This is no small machine: it's got a 12-foot-two-inch wingspan, a length of nine and a half feet, and weighs some 53 pounds. Each engine develops six horsepower, and even at idle they emit a low rumble, like a couple of lawn mowers working their way through high grass. The airplane has been built over most of the last year by Charlie Pumilia, who's brought it here from New Orleans for its maiden flight.

Formidable as it is, the Flying Boxcar is only one of many epic-scale model aircraft on display this afternoon. Over yonder is a B-17: four engines. A short distance away is a B-36: *six* engines! There's a Northrop F-20 Tigershark, a jet fighter powered by a five-blade ducted fan engine that's loud as a chainsaw. This little fireball can do 110 mph, though its builder, Joe Tamez of Fort Worth, Texas, is unimpressed. "It's slow," he says of his own model. "Some of these jets can go 190 miles an hour, 210, even more."

Diverse as they are, model airplanes at the annual Rally of Giants have one thing in common: their SIZE (left).

With realism the name of the game, these models can do almost everything full-size airplanes do (above).

Indeed, these giant-scale models can do just about everything that full-size aircraft do. They have retractable gear, steerable tailwheels, and operable flaps. The bombers have tiny bay doors that can be opened by radio control to drop miniature "bombs." The aerobatic models, which make up about half the airplanes here, are capable of performing all the usual maneuvers and then some. They do right and left snap rolls on takeoff, vertical pullups to hammerhead turns, inside loops, outside loops, Cuban 8s, lomcováks, and inverted spins, falling down through their own smoke—yes, these airplanes have radio-controlled smoke canisters. They make power-on or dead-stick landings, your choice. Then they taxi back to the ramp and shut themselves down, radio-controlled to the last.

The operative word at this fly-in, though, is BIG, as in "BIG IS BETTER," which is the motto of *High-Flight*, the World-Wide Official Quarterly Publication of the IMAA. The magazine often emphasizes important points by printing them in capital letters, thereby setting the proper example: "*High-Flight* will always remember what our organization is all about...FUN! We are going to give you what you want in a BIG way."

The IMAA as a whole clearly lives up to the motto. Where is this fly-in being held, after all, but in TEXAS? Irving, Texas, to be precise, a few miles outside Dallas. The

event is officially billed as the 11th annual RALLY OF GIANTS, the biggest and best attended of the giant-scale fly-ins. Its mid-point is June 21, the summer solstice, LONGEST DAY OF THE YEAR. What we have all around us, therefore, over 400 at last count, are not tiny airplanes, but TINY AIRPLANES!

And who flies these tiny airplanes? Tiny pilots! Seated in the cockpits are all sorts of little pilot-type figurines: buxom blondes, dashing men wearing tiny aviator sunglasses and white scarves, bug-eyed fliers in leather helmets, goggles, and parachute packs, smiling panda bears, Daffy Ducks, Mickey Mouses. Behind them all, of course, are the full-size pilots—cowboy-hatted guys stomping around on the ground wiggling the joysticks, flipping the toggle switches, and twirling the knurled knobs of their hand-held radio transmitters.

It's a sight, but this is Texas! A BIG HOWDY TO Y'ALL!

Squint your eyes a bit and, save for its lack of a pilot, the model Spitfire above could be flying over 1940 England.

Larry and Linda Steptoe prepare their still-wingless C-47 for a demonstration flight.

By early Friday afternoon some 300 pilots had registered for the meet, including two women and one nine-year-old boy. All of them have come here to have FUN because in the world of giant-scale modeling, there's no competition: the IMAA offers no cash prizes, trophies, or ribbons at its events, which is why they're called "fun-flys."

Sometimes, though, what they have here is NOT FUN, as when a truly exquisite replica of a twin-engine de Havilland Rapide rolls to the right and spins in shortly after its left engine quits. But Curly Rucker, owner and builder of the craft (which he calls his "Rapeedy"), keeps a stiff upper lip. "There's only two kinds of model airplanes," he says. "Them that's crashed and them that's gonna crash. Hell, that Rapeedy's had a good life: 125 flights before this happened."

Landings, too, are not for the fainthearted, tending to be two-bounce (or more) affairs. "The last five feet everyone's a spectator," says Tom Street, who in real life flies 737s for Southwest Airlines. "I'm a little rusty; this is only my third flight with this thing this year," he says after his T-6 Texan makes a multi-bounce touchdown. As BIG as the paved landing strip is—80 by 650 feet of black asphalt—some pilots bring their airplanes down on the grass. I asked why.

The answer: "Because they miss the runway."

The people here have come from all over—from both coasts, in fact—arriving in cars, trucks, vans, and motor homes. Jess Wright, a 65-year-old bachelor and retired engineer, drove from Albuquerque in his Ford Aerostar van towing a Plane-O-Hut behind him. This is a white fiberglass trailer that opens like a mammoth clamshell to reveal the three giant-scale aircraft he'll fly at the meet. Manufactured by an outfit in Broken Arrow, Oklahoma, the Plane-O-Hut is only one of the various commercial transporters available for these models. Like the airplanes themselves, however, many of the trailers you see here are homemade.

Not so the 40-foot-long, $400,000 Newell motor home belonging to Warren Olson, a retired aircraft dealer, and his wife Simone, who hail from Pacifica, California, just south of San Francisco. From the outside the vehicle looks much like a Greyhound bus; the interior, however, is a fabulous study in white leather upholstery and deep pile carpeting. There are televisions fore and aft, a queen-size bed in the rear bedroom, a separate kitchen with dishwasher and refrigerator-freezer, a dining area, living room, bathroom with shower, plus a laundry closet with washer-dryer—not to mention the storage space below for their fleet of giant-scale models. The Olsons put up with all this hardship on account of their dog Cookie, a Labrador retriever. "We got tired of staying in Motel 6s, which are the only motels we could find that have a policy of taking dogs," explains Simone.

From Louisiana comes a loose association

of giant-scale model nuts based in (as they say) "Nawwlins." They sit in the shade of a blue plastic canopy that's flapping steadily in the hot gusts. "Little windy today for first flights," Charlie Pumilia acknowledges, eyeing his Flying Boxcar. "But as long as this wind drops and there aren't too many people around tonight, we'll try it."

Pumilia, a 71-year-old retired architect, has been building model aircraft since he was 12. The Flying Boxcar is his current

masterpiece: all of it built to scale, and all of it operational. "There's a door in the rear of the fuselage that opens up and inward," he says. "You can open it by radio. And we have a little conveyor belt in there that's going to drop paratroopers. We have 20 paratroopers that'll come out of the door and they'll come out in a string, one behind the other, just like a jump from the real airplane. All of the paratroopers have their own individual parachutes, and after they're all out the door there's a Jeep that'll also come out and drop by parachute. And the Jeep, of course, is radio controlled too, so after it hits the ground, you drive it off."

Paratroopers, it turns out, are state-of-the-art in giant-scale modeling. "I had my C-130 rigged to drop 40 paratroopers out the back end," says modeler Bob Campbell. "That was pretty spectacular. I dropped them at Converse, Indiana, one time, on a hot day. The heat was absolutely phenomenal. I dropped those paratroops out at about 150 feet, and 35 of them just floated away because of the thermals. I never got 'em back."

Most radio-controlled airplanes can be operated from a single transmitter, but not Pumilia's Flying Boxcar. "It takes two radios to fly this plane," he says. "We need 11 different channels in order to perform all of the different functions. The first seven basically control all of the flying surfaces, the retract landing gear, and the throttles. The second radio controls everything else, including automatic cutoffs for the engines so that we can stop the engines at any time, in flight or on the ground."

Model aircraft are built either from scratch or from kits, some of which are known as A.R.F.: "almost ready to fly." (The standard quip here is " 'Almost ready to fly' means it only takes six months to put it together.") Pumilia built his C-119 from scratch, a process that took him only *seven* months, working five to 10 hours a day, seven days a week.

"And of course there were the honeydews that had to be done in between."

"Honeydews?"

"You know, when your wife comes along and says, 'Honey, would you do this for me?' "

As to the price tag for all this, "I'll tell you if you don't print it," Pumilia jokes.

"How about if I say, 'Rumor has it?' "

"Okay. Rumor has it about $3,000, with no labor. And that's holding it tight. This is allowing only $20 for the gear, for example, which we made by hand."

The $3,000 figure is fairly typical for giant-scale models, although there are wide variations either way. Bill O'Brien, who built an incredibly detailed replica of a Polikarpov biplane, paid $3,750 for the engine alone, a five-cylinder radial. "It was made by Forrest Edwards out in California," O'Brien says. "He makes only five of them a year and I was happy to get one."

Money aside, the hardest part about building some replicas is finding the right plans. When Pumilia got his C-119 blueprints, they were for a much smaller version. "We took the drawings that were supplied by this fella in Italy, blew 'em up to one-ninth the size of the full airplane, and used 'em to make the additional drawings that were necessary. We also had available to us the manuals—the original Fairchild manuals—that we looked through in order to copy the landing gear, which is a very close replica of the original."

The model's gear, admittedly, works a little differently from the original's. "It's done by compressed air," Pumilia explains. "We have a used two-liter Seven-Up bottle in there that holds 130 pounds of air pressure, and we operate the gear by means of air cylinders connected to the Seven-Up bottle."

"You're trusting it's not going to explode?" I ask him.

Flying a cherished model can try even the most steel-nerved pilots (left). Rally organizers control the number of models and radio frequencies in use by impounding the pilots' radios at registration. The pilots sign out the radios when flight times become available.

A hand-made nine-cylinder radial engine draws admirers in the exhibitors tent (below), where modelers can check out the latest in T-shirts, pins, and airplane kits.

Though megamodels are nimble and fleet in motion—the F-20 Tigershark below can do 110 mph—getting them ready to fly can be a less than graceful pursuit (right).

"It will explode at 190 pounds," he says.

"The DC-3 had a little accident with that," Pert Guidry says. "It blew the entire side off."

Guidry, another of the Nawwlins crew, an elevator installer by trade, is a former Green Beret who'd made 32 jumps out of C-119s by the time he left the service. Naturally, it was his idea to build the Flying Boxcar. The DC-3 he's talking about is standing right next to it, a gleaming silver replica of an American Airlines Flagship. It was built by Guy Lowe.

"I kind of feel bad when people think of model airplanes as little bitty things," Lowe says. "That's what everybody relates to; they don't relate to this kind of stuff. Some of us like to build bigger ones, that's all. I was in the Air Force and I like real-lookin' airplanes. That DC-3 you see out there, you can measure the real one and whatever it is, mine's going to be one-ninth of the original."

Lowe has flown DC-3s himself, as well as C-119s, Constellations, T-28s, T-33s, and F-102s. "Plus I dusted cotton in college, and I was flying a Stearman doing that."

Nevertheless, Lowe won't be flying his own DC-3 here at the meet. Being a full-size pilot doesn't help you all that much when you take the controls of a model. "When you

fly a real airplane," he says, "you physically feel the movement, and you immediately compensate for it. In this, you gotta visually *see* a movement before you know what to compensate for."

Lowe knows whereof he speaks: he once crashed a B-17 he'd built. "The tail hit a fence at a meet," he says. "Tore the tail off and it went nose-in. Ultimately, though, if you fly 'em enough, you're gonna crash 'em."

This is the philosophy that turns some of the boldest real-world pilots to Jell-O when it comes to piloting their own model aircraft. Bill O'Brien, who racked up 6,000 hours flying in the Navy, including 600 carrier landings, will not fly his own miniature Polikarpov. "I'm too nervous to do it," he says. "I let other guys fly it."

At any rate, neither Charlie Pumilia nor Pert Guidry nor Guy Lowe will do any flying here at Irving. All the actual piloting, including tonight's flight test of the C-119, will be done for them by Jerry Weinberg, a maintenance mechanic for Shell Oil.

So where is he?

"I don't know where Jerry is now," Guidry says, looking around. "Probably takin' some nerve pills."

No one knows exactly when the first model aircraft was built, although homebuilt gliders were being flown at least as far back as the 1800s. The Wright brothers experimented with models, as did aircraft designer Burt Rutan, who wrote a college thesis based on a model he designed and flew by radio control. Today aircraft modeling is a growth industry, and the Academy of Model Aeronautics, located in Reston, Virginia, has a membership of 167,000. Neil Armstrong was a member; astronaut Hoot Gibson still is.

The International Miniature Aircraft Association, home to giant-scale modelers, is not formally a part of the AMA, but many of the IMAA's 7,000 members belong to the AMA, primarily because it offers members liability coverage just in case one of their flying machines should happen to interface with a bystander. To make this insurance affordable, though, some weight limitations had to be imposed.

"Big airplanes are beautiful and fly extremely well," says Vince Mankowski, executive director of the AMA. "But there were some basic questions: What's a model aircraft? What's a real aircraft? Where's the dividing line?" After some heavy thought AMA officials came up with a 55-pound weight limitation for AMA insurance. This restriction has irked some members.

You could call them a bit, well, plastic, but the tiny figures modelers place inside their airplanes embody a full range of their makers' whimsey. An auburn-haired stunt flier and a cocky fighter pilot appear cooly confident (top, middle); a B-17 tail gunner looks anything but (bottom).

"I did a 16-foot B-29 that weighed 140 pounds," Bob Campbell tells me at the Texas meet, "but I can't fly it here."

Campbell is a fixture in the giant-scale community. It was his B-29, in fact, that appeared in the movie *The Right Stuff:* appearances to the contrary, that's not a real B-29 dropping an actual Bell X-1 out of the bomb bay; it's two of Campbell's models.

"And then I did a Super Connie," he continues, "another 16-footer. And after that I did the B-17 *Memphis Belle,* with a sixteen-and-a-half-foot span. I did a C-130 which was a 20-footer and weighed 210 pounds; I flew that one all over the country. And I started a B-36 about five or six years ago and it would have been even bigger: 24-foot wingspan, projected weight of 300-odd pounds. I even had the fuselage built. I had the wing all cut out. And I was going on with the project when the insurance liability thing hit."

To this day, Campbell cannot come to terms with the weight limitations. "The B-36 is a *bomber,*" he says. "It's made to carry a lotta weight, right? It *should* weigh a lot. It's *supposed* to weigh a lot. It *flies better* when it weighs a lot. It's not supposed to be a goddamn high-performance glider!"

Late that afternoon the wind has died down, and designated test pilot Jerry Weinberg is worried that he may actually have to fly Charlie Pumilia's C-119. "I feel nervous every time I fly," he says. "The first flight on the DC-3 my knees were shaking, my mouth was dry...and it doesn't change! After you get a couple of flights on it that day, then you're all right."

All four of the Nawwlins boys, one at each wing and one at each tail boom, carry the C-119 to the flightline. Where things go wrong from the start. Weinberg switches on his transmitter and the gear retracts smartly, dropping the airplane to the ground with a clunk. The retract switch, unfortunately, had been left in the "up" position.

He extends the gear again but now the nose wheel refuses to lock, and in fact the slightest bit of pressure collapses the nose gear altogether. At this point Weinberg decides that he would really rather not go through with the flight test, but Pumilia, who *built* the plane, who *paid* for it, who brought it here all the way from Louisi*ana,* wants to see his creation up in the air. He's been waiting all day for this! All these people are standing around!

"Just lift it off a little bit," he pleads. Weinberg shakes his head.

"See what happens." But Weinberg says no.

"At least taxi it out on the runway."

All right. Still, they've got to keep that nose wheel down somehow. After considerable deliberation the modelers elect to avail themselves of that indispensable component of all homebuilt flying machines: *whaar* ("wire" in Louisianan), and soon three of the men are lying on the ground with their hands deep inside the wheel bay, whaarin' the nose gear into position.

After an eternity the engines start. "How do you like the sound?" Guy Lowe asks, and Weinberg nods his approval. The two perform a static run-up with Lowe holding onto the rear of the airplane—he has gotten to be very good at this, but one time in Memphis he grabbed onto the tail of his DC-3 a bit too late during run-up and the entire vertical stabilizer-rudder assembly came off in his hands—and when this is completed Weinberg finally guns the craft out onto the asphalt.

Well now!

He advances the throttles and the C-119 starts moving down the runway. But suddenly the nose comes up—this without his applying any up-elevator back pressure whatsoever. Weinberg yells, "It's *tail* heavy."

He works the airplane up and down the runway—no lifting off, just fast taxiing—and the same thing happens every time: the nose tilts up prematurely and the tail booms hit the ground.

"It's tail heavy," he says again. "Very sloppy."

And all at once it's clear to everyone that the C-119 will not be flying at the Irving meet; a maiden taxi will have to do. A few more fast runs up and down the airstrip and Weinberg brings the airplane back to the ramp and shuts down.

"What's the solution?" I ask Lowe.

"Lead," he says. "I've got an Avenger back home with 17 pounds of lead in it."

It's the last full day of the meet, and Nick Setar of San Antonio, Texas, is guiding his Roadrunner through the airborne chaos. He's the very picture of *sangfroid,* eyes glued to the airplane, not flustered in the least degree by the four other giant-scale models barreling along in various suicidal attitudes above him.

Nick is nine years old.

"My brother and my father had been flying for a while and then I got interested,"

So detailed is the SBD Dauntless model above that pilot and gunner figurines inside it are decked out in tiny G-1 leather jackets, complete with even tinier fur collars.

With its monumental wingspan and six working engines, Grant Wilson's B-36 proved one of the highlights of the rally (right).

he says. "I got an Eagle for Christmas—an Eagle Two, a trainer. My little brother crashed my Eagle—he's nine too [they're twins]—and he was flying it. He hasn't soloed or anything, and he was flying mine and the wings collapsed because he was being too jerky with it. Boy, I got really mad at him! And I soloed with an Aerostar, and then from the Aerostar I went to these quarter-scaler things."

This morning Nick uses his full 10-minute flight time and then makes an approach and the standard two-bounce landing.

"I had a great time," he says afterward. "When I first took off I was a little nervous because the trims were off, but I got 'em fixed and then I had a great time."

Like everyone here, Nick, who wants to be a pilot when he grows up, likes BIG airplanes. "They're more fun," he says, a viewpoint you can hear as much as you want.

But in fact the romance of these large and lovely, full-figured, great big fat model aircraft does not become entirely clear for me until the triple DC-3 flyby.

Each one is a replica of a historically great DC-3: Guy Lowe's, an American Airlines Flagship; Tom Holmsley's, a Trans-Texas Airlines DC-3; and finally Larry and Linda Steptoe's C-47 (the DC-3's military designation), a copy of the airplane the Navy landed at the South Pole in 1956. They're all lined up on the runway now, facing in precisely the same direction, just as if this were La Guardia in the '50s.

They taxi into position, hold for a moment, and then launch into the blue—one by one, no formation takeoffs here—each with a ground roll of about three seconds, but otherwise looking, you have to admit, quite realistic. They sound it too, because you can hear the synchronization of the engines, you can even feel it: the yawning, droning hum just like the full-size versions make.

The airplanes fly a circuit or two, then gather a little closer, still not truly in formation because it's hard to judge horizontal separation from the ground. And suddenly these three Douglas transports are in a single pack and turning final, coming right at you, slow stately banking turns, a great throbbing roar of six engines. Yes, this is a pretty sight.

Then from the loudspeakers: "Someday this will be the only way you'll be able to see three DC-3s flying together anywhere in the world—with model aircraft."

Nobody disagrees, and in fact there are many nods, yeses, and ayuh's from the crowd. And now, for sure, you can see the whole point: these tiny airplanes are real things in their own right. Truly, they are miniature aircraft, not cartoons, not toys.

Finally they make their approach. Throttle back. Flaps. Gear down.

Flawless, airline-quality landings: mystical two-point touchdowns, not a bounce among 'em. Wild applause.

"It's a gentle hobby," says Pert Guidry. "We've had some good times. And it's not the competition, it's the camaraderie. Once a year you get to visit with all these people. You may not see somebody for a year, but you look forward to seeing him again. You meet a lot of good friends out here."

"It's a tremendous hobby," Charlie Pumilia says. "Lots of fun, lots of fellowship. Generally, it's a good way to spend a life."

A sudden treetop landing resulted in only a small nick to the fortunate model above, which will go on to fly again. Modelers say crashes are inevitable and often totally demolish the aircraft.

Mike Darnell's Wagner Twin Cub, a scale model of an airplane built in 1949, has two fuselages, two engines, and two carefully staggered propellers (left).

Like a large, docile pet, a model biplane trundles along behind its builder after surviving a minor mishap (below).

Surveillance satellites are amazingly sophisticated, but the results they yield are only as good as the people using them.

The Spies in Space

by Jeffrey T. Richelson

In the middle of July 1990, American KH-11 satellites passing over the Middle East began transmitting disturbing imagery of the border between Iraq and Kuwait. The satellites' optical systems previously had seen only empty desert there, but now they showed an Iraqi division equipped with the modern T-72 tank. The next day the satellites' transmissions showed evidence of a formidable Iraqi force of 300 tanks and 10,000 men, plus a division of the Republican Guard. By the third day, the satellites' photo interpreters estimated that 35,000 Iraqi troops were poised on Kuwait's northern border.

Among those examining the imagery was Walter P. "Pat" Lang. A retired Army colonel, Lang was the Defense Intelligence Agency's officer for the Middle East and South Asia. Fluent in Arabic, he had traveled to Iraq half a dozen times and served as military attaché in Saudi Arabia in the early 1980s. Lang was worried by what he was seeing, and he wasn't alone. Charles Eugene Allen, the national intelligence officer for warning, became convinced that Iraq's Saddam Hussein was preparing to attack Kuwait. On August 1 he warned the National Security Council's Middle East staff that Iraq would invade Kuwait by the end of the day.

U.S. satellite imagery eventually arrives at the National Photographic Interpretation Center in Washington.

But despite the satellite images and the warnings from Lang and Allen, the top intelligence and national security officials, including President Bush, felt that Hussein was bluffing. The satellites had made their contributions, but their human masters chose to interpret their images optimistically.

The intelligence failure before the Gulf war underscores one simple fact: spy satellites are only as effective as the people who use them, in part because they do not provide *information*, they provide data. It takes a human partner to glean information from that data and to act upon it, and it's the human side of the partnership that determines if the satellite is a success or a failure.

That satellites are valuable tools for intelligence gathering was demonstrated early in the Space Age. Satellite images of the Soviet Union taken in the early 1960s backed up evidence from U-2 flights that the feared missile gap was a myth—that rather than having hundreds of intercontinental ballistic missiles aimed at the American heartland, the Soviets had, at most, ten.

Several years later President Lyndon Johnson told a group of educators, "I wouldn't want to be quoted on this, but we've spent 35 or 40 billion dollars on the space program. And if nothing else had come out of it except the knowledge that we've gained from space photography, it would be worth 10 times what the whole program has cost. Because tonight we know how many missiles the enemy has, and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor."

Despite their great value, the early reconnaissance satellites were far from perfect. They returned their images by parachuting the film back to Earth in a capsule, sometimes days or even weeks after they were taken. That delay could be crippling. Both the 1967 Six-Day War in Israel and the Soviet invasion of Czechoslovakia in 1968 ended before the United States could obtain satellite imagery of the trouble spots.

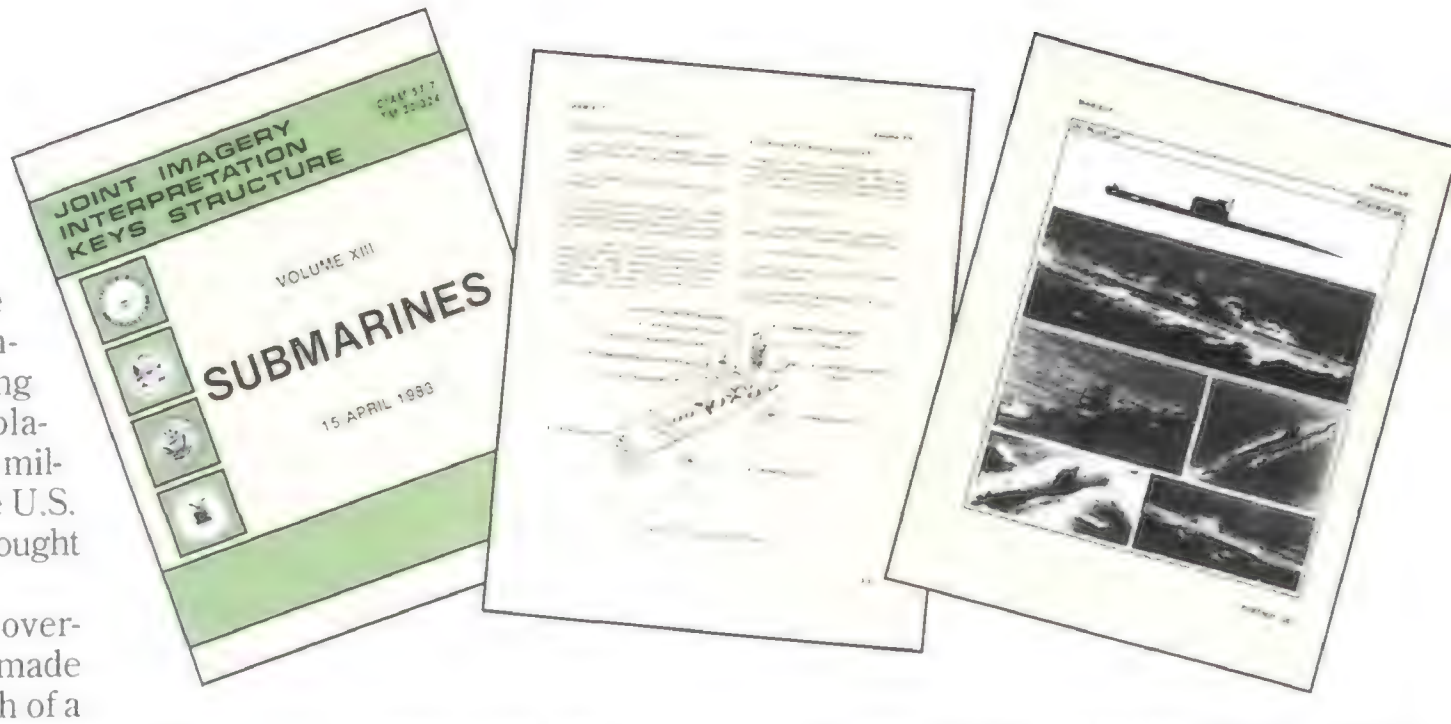
After the 1973 Yom Kippur War, one analyst with the Central Intelligence Agency recalls, "we had wonderful coverage but we didn't get the pictures until the war was over." The lack of timely intelligence was judged by the Pike Committee (established in 1975 to investigate U.S. intelligence activities) a serious threat to the United States. The

KH-11 capabilities were revealed to the world in 1984 when U.S. naval analyst Samuel Loring Morison leaked photographs to Jane's Defence Weekly. *The pictures, taken from an oblique angle 504 miles away, showed a Soviet nuclear aircraft carrier under construction (left). Morison was jailed for the leak.*

United States had been forced to rely on overly optimistic Israeli battle reports. As a result, reported the committee, "[t]he U.S. clashed with the better-informed Soviets on the latter's strong reaction to Israeli cease-fire violations. Soviet threats to intervene militarily were met with a worldwide U.S. troop alert. Poor intelligence had brought America to the brink of war."

The quantum leap needed to overcome such intelligence gaps was made in December 1976 with the launch of a satellite known by the top-secret program name Kennan and more widely as the KH-11 ("KH" being shorthand for KEYHOLE, the designation of an imaging satellite, and "11" indicating the 11th optical system used by the KH satellite series). Unlike earlier KH satellites, KH-11s can return imagery almost instantly. They also have relatively long lives, sometimes remaining active for several years. During daylight passes in good atmospheric conditions, the satellites can obtain clear pictures in which objects only six inches apart can be distinguished (see "The Vision Thing," page 78).

The KH-11s transmit their data to ground stations, where it is recorded on tape and shipped to imagery interpreters. Because the satellites can send back a picture about every five seconds, many of the images are simply stored. They can be scrutinized later if events require it. Others are viewed immediately and become one more piece of the larger intelligence picture. And still others become the catalyst for further collection efforts and eventually for action—political, diplomatic, or military.



Specialized interpretation keys aid photo interpreters with their identifications.

Even in the post-Cold War era there is no shortage of reconnaissance targets. Satellite imagery of the Soviet Union is vital for arms control verification and for monitoring the volatile situation there. Satellites search for signs of new nuclear reactors or missile deployments in countries that buy arms and nuclear technology from China, including Algeria, Iran, Iraq, Pakistan, Saudi Arabia, and Syria. The United States' eyes in space even keep watch over sites in the Western Hemisphere, from drug production facilities in Bolivia and Columbia to possible advanced weapons in Argentina and Brazil.

Eventually all of this imagery will end up in a windowless building in the Navy Yard in Washington, D.C. The National Photographic Interpretation Center is run by the CIA and staffed by interpreters from the CIA, the Defense Intelligence Agency, and various Army, Navy, and Air Force intelligence organizations. The CIA, DIA, and military intelligence organizations also maintain their own interpretation divisions. Riding herd on the "exploitation" process, as it is called, is the director of the CIA's Committee on Imagery Requirements and Exploitation, which divides the imagery interpretation task among the different agencies.

Even if presented with the best overhead imagery, a layman would glean only a fraction of the intelligence extracted by skilled interpreters. In his book *Thirteen Days,* Robert Kennedy recalled the photographs a high-flying U-2 spyplane took in 1962 of Soviet missile sites being set up in Cuba, images that sparked the Cuban Missile Crisis. "I examined the pictures carefully," Kennedy wrote, "and what I saw appeared to be no more than the clearing of a field for a farm or the basement of a house. I was relieved to hear later that this was the same reaction of virtually everyone at the meeting, including President Kennedy."

The people who analyze satellite pictures are trained to extract the maximum amount of information. They use interpretation keys—volumes that contain satellite-eye views of everything from submarines to aircraft. "Each weapons system has a signature," says retired CIA photo-interpreter Dino Brugioni. "An ICBM site, for example: the

The KH-11

Operating in polar orbit at altitudes between 150 and 250 miles, each KH-11 passes over every region of the world twice a day, once during daylight hours and once at night, though only the daylight pass provides useful imagery. The heart of the 25,000-pound satellite's surveillance system is the charge-coupled device. The silicon chips of a CCD, like the electro-optical system of a television set, are made up of light-sensitive picture elements (pixels) that emit electrical signals in proportion to the amount of light that strikes them. The signal from each pixel receives a numerical value, and this data is then transmitted to the spacecraft of the Satellite Data System. The SDS satellites in turn relay the signals to a receiving station at Fort Belvoir, Virginia, just south of Washington. There the digital signals are reconstituted into imagery.

On August 8, 1989, the space shuttle *Columbia* deployed the first of a new family of KH-11s: the advanced KH-11 (sometimes incorrectly referred to as a KH-12). In addition to providing visual imagery, the advanced KH-11 has sensors to detect infrared (heat) energy. Since objects on the ground emit heat both night and day, the advanced KH-11 has some nighttime capability.

signature for an ICBM site is modern roads with wide-radius turns that end up at a secured area. The reason you have to have wide-radius turns is you're dealing with a missile that's about 100 feet long and you can't come up to a crossroad and turn the thing. The other thing is that you have a multimillion-dollar missile and you're not going to trundle it over bad roads."

Interpreters also examine the image in context, relating an object to its surroundings. Says Brugioni, "I always advocated that you take out picture books of the country that you're dealing with. A domed building in the United States is, in most probable cases, a radar dome. You can't apply that to the Middle East. In each case you work with a pattern and you begin to learn how people live and you take that and you develop a series of signatures about the particular country you're working with."

Even the most skilled interpreters can make mistakes. Shortly after the Six-Day War, CIA photo interpreters were alarmed by a satellite photo of Israeli territory that clearly showed a circular excavation—the kind of digging associated with installation of a missile silo—near the Gaza strip. Closer study revealed that the excavation was, in fact, a watering trough.

When satellites used film to photograph their targets, the ability to manipulate and enhance the imagery was limited. The film could be scanned with a laser, converted into digital form, and then manipulated, but many times the very act of developing the film destroyed valuable information. When an image was cloaked in shadows, often all that was left after the film was developed was the shadow. With the arrival of the KH-11 and its digital imagery, image enhancement with computers became an enormously valuable tool in the interpreter's arsenal.

Though the details of intelligence image enhancement are secret, similar work is done at the Jet Propulsion Laboratory in Pasadena, California. JPL's image enhancement software includes nearly a thousand programs for enhancement work, according to Kevin Hussey of the image processing lab. For instance, when a target is partially obscured by cloud cover or haze, the computer can compensate by eliminating the clouds. Another technique allows computers to compare images of the same target taken at different times and immediately detect any changes, such as new construction, movements of motor vehicles, or excavation. It is also possible to improve resolution by using a computer to combine multiple images of a single scene. And a "de-spiking" program will automatically flag any pixels with values so bright or dark that they stand out from their neighbors, either replacing them with more average values, or alerting analysts of the discrepancy. Averaging two or more images of the same area also allows the computer to filter out any aberrant pixels and get a more realistic view of the target.

But even with computers, satellites alone cannot provide a full picture of what's going on below them. The KH-11 images from Iraq that had concerned Pat Lang and Charles Allen might have been more persuasive to others if they had been supplemented by two other forms of intelligence—human intelligence from old-fashioned spies and intercepted signal communications. But as former CIA director William Webster noted in late 1990, human intelligence concerning the intentions of world leaders "is often difficult to acquire and, frankly, very difficult to acquire in an autocratic environment." And Saddam Hussein's Iraq was more autocratic than most countries, with a fearsome secret police. Further, Hussein and his subordinates were well aware that the U.S. global eavesdropping network can snatch almost any communication out of the air. To avoid being overheard, the Iraqis

LACROSSE

Not even the advanced KH-11 can see through clouds, and since the Soviet Union and part of Eastern Europe are under cloud cover for as much as 70 percent of the year, that posed a problem for U.S. intelligence. The two LACROSSE satellites currently in orbit were designed to alleviate that problem. Operating about 400 miles above Earth, the satellites bounce radio signals off a target and convert the returning signals into imagery. The images are sent back to Earth via the Tracking and Data Relay Satellite System (TDRSS). The resolution doesn't equal that of KH-11 imagery—LACROSSE's has been reported as ranging from three to five feet—but then the KH-11 can neither see through clouds nor very well at night.

COURTESY WILLIAM E. BURROWS

Accidentally printed in a 1984 Congressional record, these satellite photos (not from KH-11s) show a Soviet MiG-29 (left) and Su-27.

The Vision Thing

We often hear that U.S. spy satellites, orbiting 200 miles above Earth, can read *Pravda*, or at least the license plates on cars driving in and out of the Kremlin. But can they really? The people who could tell us are muzzled by oaths of secrecy, but we can still make an educated guess at spy satellites' capabilities. Looking down from a satellite to see what's happening on the ground isn't too different from looking up at the heavens to see what's happening there. That's something astronomers have thought about a lot, so as an astrophysicist I shouldn't be too far off in giving you my view of what we may be able to see and record from orbit.

We can start with a few well-known, published facts about spy satellites. During the 1980s the United States attempted to phase out all other heavy-lift vehicles, so virtually all of these satellites had to be small enough to launch on the shuttle. The biggest telescope that can fit into the shuttle bay is the size of the Hubble Space Telescope, with a light-gathering mirror just 2.4 meters, or roughly eight feet, in diameter. We can assume that the lenses or mirrors on spy satellites aren't much larger than that.

We also know that satellites tend to fly at an altitude of about 200 miles (though the advanced KH-11s are a little higher). Much lower, and atmospheric drag becomes significant enough to cause the satellites to fall back to Earth.

The next factor to take into account is the characteristics of visible light, especially wavelength—the distance separating successive wave crests of light. Wavelength is important because it determines the amount of detail we can discern. The shorter the wavelength, the more detail we can hope to gather. It acts a bit like the scale markings on a set of calipers. With fine scale markings we can at once see small differences in size; conversely, the coarser the scale we use, the more difficult it becomes to differentiate size.

Some cameras can respond to ultraviolet light, which has a wavelength shorter than anything the eye can see, but ultraviolet radiation is rather easily absorbed by the atmosphere—otherwise all of us would suffer terrible sunburns—and isn't likely to make it through the atmosphere to a satellite. Other satellite cameras can sense infrared, or heat, radiation, which has a wavelength longer than that of visible light. Such cameras are capable of photographing warm bodies in darkness, but they can't provide as much detail as a visible-light camera. A different class of satellites, like LACROSSE, gathers images with the very long wavelengths of radar, but the details in these images can't compare to those from visible-light cameras. Radar satellites primarily sense the elevations and compositions of structures and terrain.

Another fundamental property of waves is an effect called diffraction—the change in a wave after it passes through a narrow passage such as a camera aperture (the opening that allows light onto the mirror or lens). Diffraction prevents us from focusing light waves onto a spot smaller than a certain minimum size; it produces a slight smearing of fine features on even the very best images we can obtain. The laws of diffraction tell us that the smallest recognizable details in a picture taken by a satellite can be determined by multiplying the altitude of the satellite by the wavelength of light and dividing by the camera aperture.

To put it into an equation: smallest discernible size = wavelength X satellite altitude/camera aperture.

Now plug some numbers into the equation. The shortest wavelength of visible light is roughly one-hundredth the thickness of a human hair, or just slightly greater than a millionth of a foot. A satellite in a 200-mile orbit is about one million feet up. Multiplying those two numbers together, we get a value just slightly larger than one. And since the camera aperture is eight feet (the size we determined for the mirror), we find that the smallest barely discernible object viewed from a satellite altitude is just over 1/8 foot, or a little larger than an inch and a half. With that much resolution, we could probably distinguish an *E* from a *B* or a *3* from an *8*, provided those letters and numbers were about the normal license plate size, about 2.5 inches.

All this is true provided nothing moves and blurs the picture, but satellites in low Earth orbit move very fast in relation to the ground: roughly five miles a second. There are two ways to reduce the blurring this causes: we can take fast exposures, or we can compensate for the satellite's motion by swiveling parts of the camera.

In good sunlight, we can cut the exposure time to around a thousandth of a second. Satellites use highly sensitive photo surfaces, so an exposure about that fast should work. But is it fast enough? In one millisecond—one thousandth of a second—a satellite moving at five miles a second moves 25 feet with respect to the ground. During this exposure, the four-inch numbers on a license plate would be smeared out over a 25-foot swath unless the camera could track the objects on the ground the way a skeet shooter leads his target. That could be done with a tilting mirror synchronized to the camera exposure, but that requires good control and a very stable satellite.

Let's assume that all this is possible. The satellite will produce its imagery by breaking down the scene it views into squares an inch and a half on a side—the smallest discernible size. The light from each of those squares is captured on a light-sensitive element in the camera, called a picture element, or pixel. (Televisions use pixels to create their images too, with roughly 500 pixels on each side of the image.)

The next limitation a satellite faces is transmission—getting its images to the ground. Today's satellites usually use a radio link, and the fastest rate at which today's radio transmitters can send information is two billion bits—pieces of information—per second. The pictures recorded by the camera cannot be conveyed to the ground faster because information cannot be transmitted at a rate that exceeds the bandwidth—the number of different wavelengths—over which the radio transmits information.

We can think of each of these individual wavelengths as equivalent to a different color, with each color, or color combination, carrying its own message. Aviators are familiar with this concept. An airport tower using lights of three colors—white, red, and green—could transmit up to eight different messages: white, red, green, white plus red, red plus green, green plus white, all three lights, and no lights at all. No matter what meaning we attach to these light signals (such as "extreme caution" for the red-green combination), each color is capable of transmitting just one bit of information.

As the number of pixels used to render this image increases, so too does the clarity, and an abstract collection of squares resolves itself into an infrared aerial view of Washington, D.C.

If we have two billion wavelengths (colors), they can transmit two billion bits of information.

But how do two billion bits translate into a picture? To transmit information about each picture element in true color and with accurate brightness levels, we might use around 20 bits of information to characterize each pixel, and that's a lot of radio capacity to describe just a single point. We can be more economical, however. For example, if two or more adjacent pixels have the same color and shading, we might not need to specify all that detail for the second point; instead we might simply say the electronic equivalent of "ditto," a word that can be represented by a single bit. That way, instead of using a full 20 bits to define a picture element, the final average for an entire scene may be only five bits per pixel. In that case a radio link transmitting two billion bits per second can provide all the information we need to reproduce a high-fidelity, 400 million-pixel picture each second. Four hundred million pixels each second translate into 400,000 pixels per frame, which reduces to an array of 200 x 2,000 pixels. Each of those pixels represents a 1.5- by 1.5-inch element on the ground. I've picked such an oblong array because 200 1.5-inch pixels corresponds to a 25-foot length, which is the distance the satellite traverses in a millisecond. In effect, this means that by moving over the ground at the rate it does, the satellite could transmit back pictures covering only 2,000 pixels, or a 250-foot-wide swath, on a continuing basis.

That's not very useful for several reasons. Let's say we wanted to build up a picture of a large city, perhaps 20 miles (100,000 feet) across. We would need to make 400 passes of the satellite over that city to obtain a full picture. On average, a satellite can pass over the city only twice a day, and one of those passes is at night. So it would take 400 days to obtain a full picture of the city in such high detail. And that's not even counting cloudy days, when no picture information can be obtained.

Given all these difficulties, what exactly can spy satellites discern?

In all probability, they can resolve limited scenery of special interest well enough to see items the size of the numbers on a license plate. (Since license plates are rarely mounted on cars so that they can be read from straight up, the satellite would have to read them from an oblique angle, and therefore from somewhat farther away than 200 miles. Under such conditions, a spy satellite probably would still just be able to monitor the plate numbers of cars entering and leaving the Kremlin.)

But it wouldn't make sense to scrutinize large areas in such detail. That coverage would be better obtained from satellites in much higher geostationary orbits. The details would be coarser, but sufficient to distinguish a car from a truck if not enough to recognize the make of the car. If the activities in one particular area appeared suspicious, we could direct a satellite in low orbit to obtain a close-up view revealing much greater detail of just that one scene.

All in all, spy satellites probably provide a mix of different kinds of pictures, some very finely detailed but limited to confined scenes, others much coarser but also more panoramic. I suspect that the panoramic pictures are the daily staple of the trade, and when some area appears to undergo rapid activity, finer detail is sought for closer analysis.

Seeing objects as small as a few inches is not doing too badly, and with the resources at hand, we probably can't do much better than that. The laws of physics don't give us much leeway.

—Martin Harwit

transmitted much of their important information via fiber optic cables and other land lines, rather than transmitting through the air.

Nations may also attempt to foil a satellite with denial and deception operations. Denial methods may be as simple as stopping an activity or placing equipment under a cover or inside a building before a satellite passes overhead. Deception operations seek to mislead the imagery interpreters. The deceivers may deploy dummy aircraft and tanks, paint patterns on buildings that suggest bomb or fire damage, or camouflage military hardware. But photo interpreters have ways to unmask the deception. According to Dino Brugioni, "If the Soviets put up dummy aircraft, you never see them being serviced. If they put up rubber dummies and decoys you see them smashed as the weather and seasons change."

Sometime around December 1987, a KH-11 detected a construction site 40 miles south of Tripoli, the capital of Libya. By July 1988 enough intelligence had been acquired from KH-11 and SR-71 photography, communications interceptions, and human sources (including Arab and Western workers at the site) to convince CIA analysts that Muammar Qaddafi was definitely building a chemical warfare facility.

Having been caught red-handed by the satellites, Qaddafi tried to use them to undo the damage. The buildings at the complex were painted with "burns" to support a report by the Libyan news agency that a fire had erupted at the complex. But U.S. intelligence analysts who examined the imagery were not fooled. "It clearly was an attempt at deception," one senior intelligence official told the *Washington Post*, and the attempt was "not particularly well done."

During the war with Iraq, the United States operated an unprecedented number of imaging satellites simultaneously—three KH-11s (launched in 1984, 1987, and 1988), three advanced KH-11s (launched in 1989 and 1990), and one LACROSSE (launched in 1988). In the five and a half months between the invasion of Kuwait in August 1990 and the beginning of the air war, U.S. satellites closely scrutinized Iraq for sites to target for attack.

The imagery arrived in the field ei-

The defense department zealously guards satellite imagery. When explaining an Iraqi attempt to fake bomb damage to a mosque, briefers used aerial photos (pictured) and sketches made from satellite imagery, but not the satellite images themselves.

ther from Washington (after processing) via communications satellites or, according to *Aviation Week and Space Technology,* directly from reconnaissance satellites transmitting to small mobile terminals in the theater of operations. In a speech in August 1990, Air Force Brigadier General Donald Hard announced that imagery "is provided directly to the field, to allow informed and accurate decisions for mission planning and battle management."

But the war also demonstrated the limits of satellite imagery. One difficulty was effective damage assessment. Sometimes the results of a bombing raid were clear, but at other times the damage was out of the satellites' view: munitions, particularly "smart" bombs, could simply have punched a small hole in a roof or entered via a duct and done their damage inside. In such cases intelligence analysts would not consider the target destroyed.

The limitations of imagery and the utility of other forms of intelligence were tragically illustrated on February 12, when allied aircraft bombed a reinforced-concrete building in Baghdad. Intelligence had pinpointed the structure as a command and control facility and, according to some reports, a leadership shelter. But the facility also served as a civilian shelter, possibly for relatives of the Iraqi leadership. As many as several hundred civilians were killed in the attack.

Military briefers in Washington and Riyadh confirmed that satellite imagery played a key role, though not the sole one, in identifying the facility as a command and control center. Captain David Herrington, deputy director of intelligence for the Joint Chiefs of Staff, noted that the U.S. had observed that the building had "a camouflage roof [and] a security fence around it with barbed wire." Joint Chiefs of Staff director of operations Thomas Kelly recalled: "We saw military vehicles parked outside it, we saw military people going in and out of it...." U.S. satellites also spotted communications equipment that had been hardened to survive a nuclear blast.

Other forms of intelligence supported the satellites' observations. Intercepted communications had indicated that the facility was being used for command and control purposes, and as Riyadh briefer Brigadier General Richard Neal noted, "We talked to folks that worked in the construction area" who described the installation of sophisticated equipment that was hardened against military attack. Unfortunately, there were no human sources to provide information on exactly how the facility was being used. If the civilians had entered the shelter in the middle of the night, it would have been difficult for satellites to detect them. The deaths of those civilians illustrated that, as Colonel Andrew Duncan of the International Institute of Strategic Studies observed, "No matter how many satellites you have overhead...nobody can see through a roof."

That is unlikely to change. Instead, the challenge is to be found back on Earth: in combining different types of imagery (visible light, infrared, and radar) and in developing better methods to ensure that the flood of imagery is processed, analyzed, and distributed efficiently, particularly in critical combat situations.

It is clear from their comments that U.S. military commanders in the Persian Gulf, including General Norman Schwarzkopf, found the system for producing and distributing overhead photography to be deficient. Among Schwarzkopf's complaints was that field commanders and pilots could not get reconnaissance photographs of potential Iraqi military targets that were less than a day old. "It was a void that all of us felt," the general said.

The delay was caused by two problems. Even with the large number of satellites in orbit, the United States was not able to image every target on a daily basis, particularly when cloud cover was present. In addition, interpreters were swamped by the volume of incoming imagery, resulting in 18-hour workdays at NPIC. But it is unlikely that this country will ever have the financial and human resources to ensure that all targets are monitored and the imagery analyzed every day.

William E. Burrows, the author of *Deep Black: Space Espionage and National Security,* observes, "It's a paradox. Real-time imaging from several spacecraft, particularly in a crisis, can return an avalanche of information. That's the good news. But the more data you collect, the more you struggle to process, interpret, and move it. The bad news is that an avalanche can bury you alive."

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AVIATION WEEK & SPACE TECHNOLOGY

The man behind aviation's gossip sheet has heard—and told—it all.

by Edwards Park

Illustrations by Robert Osborn

True Confessions

COURTESY REX HARDY

In 1979 Rex Hardy started Callback, *an aviation "Idunnit."*

Picture an airline captain ferrying a load of passengers to a busy airport. He's got his hands full on the flight deck—there's weather radar and traffic to monitor, landing checklists, cabin announcements, paperwork, and a running dialogue with air traffic controllers. There's also an aircraft to fly.

The captain delegates the flying to the first officer, who's already swamped, and starts on a checklist. He hears air traffic control clear him to descend to 5,000 feet. A minute later he notices the altimeter unwinding through 4,200 feet. Both pilots have been too preoccupied to catch the error. Suddenly a little Cessna slides right over the nose, maybe 200 feet away, and the captain realizes he nearly made tomorrow's headlines.

Or imagine a controller in a darkened center, eyeing monitors covered with dozens of scurrying blips, each representing an airliner. She calls one aircraft and clears it to descend to FL280 (a flight level of 28,000 feet). She clears another to climb to FL270, 1,000 feet below the first, which she then instructs to fly a heading of 240.

The first pilot acknowledges, "Roger, two four zero" and heads down, right through the other airplane's altitude. He thought he was being issued a new flight level, not a new heading. The two blips draw dangerously close before the controller gets the errant pilot back up where he belongs.

Then there's the crew that walks away from their parked and chocked airlin-

er leaving the number-two engine running; the fogged-up windshield; the bird colliding with the pitot tube; and hundreds of other lapses in flight safety.

The military has its own reporting system for near-mishaps, and the weekend pilot may swap horror stories with peers on a rainy Sunday. But the crop duster, charter pilot, and instructor generally keep mum when they forget to put the landing gear down or check the fuel tanks. And the airline captain faces more conflicts than a fighter jock. Aborting a landing because of a thunderstorm over the airport makes good sense, but if he misses an approach, the company gets on his back for wasting fuel. Delaying a takeoff because of a faulty fuel flow gauge is a wise decision, but the sales manager in 27F has to get to Cleveland by 10 to earn his commission, and he's thinking lawsuit. Badgered on both sides, the captain who busts his assigned altitude and has a near-collision may say to himself, "I'll never do that again, but I'll never tell a soul about it either."

In October 1974 a United Airlines DC-8 descended below the safe altitude on the way into Dulles airport in Virginia and almost hit a mountain. The captain's report, which appeared in a circular on United's flight safety program, illustrated the different ways controllers and aircrews interpret "Cleared for the approach." Six weeks later a TWA 727 on the same approach did hit the mountain. TWA had never been apprised of United's report.

The following year, that deadly lack of communication inspired the Federal Aviation Administration to establish the Aviation Safety Reporting System (ASRS), an open channel designed to keep pilots and air traffic controllers informed about dangerous mountains, hazardous cockpit mixups, and any potentially unsafe conditions or incidents. The idea was fine, but not so the sponsorship. Enumerating your mistakes to an FAA-run department seemed like entering a confessional with a sheriff behind the curtain.

To its credit, the FAA recognized the conflict of interest and asked NASA to lend its ear to confidential reports. In 1976, NASA set up ASRS offices at Ames Research Center in California and established an elaborate security system to keep sinners anonymous. NASA ARC 277 reporting forms were mailed to all active pilots, and an identification strip that called for the reporter's name, address, and phone was torn off and returned to the sender after ASRS processing. Even if a report described a violation of a Federal Aviation Regulation, no penalties or suspensions would be assessed as long as the violation was not deliberate, the reporter was not a repeat offender, and the report had been filed within 10 days of the transgression. That summer, assured that they wouldn't lose their jobs by helping others save their necks, pilots, mechanics, and controllers began flooding the analysts—a veteran pilot and a controller—with more than 100 confessions a week. More analysts were added to deal with the rapidly building backlog, and soon all reports were being analyzed, diagnosed, and fed into a computer database.

COPILOT was flying; I was working the radios. Approach Control cleared us for ILS [instrument landing system]. At 1500 feet we encountered a bird strike. Evidently I did not change over to Tower, as the bird strike distracted me.... The first time we recognized that we had landed without a clearance was when Ground Control said, "The tower says you are cleared to land." It is obvious that as Captain I should have made sure we were cleared to land, but I also think that Approach should have said something to us..

ON TAKEOFF the aircraft demonstrated the performance of a lead sled. The Captain's concern prompted a check and double check of fuel, cargo, and passenger weights. It took a bit of doing to determine that most of the passengers were attending a coin-collectors' convention and had carry-on bags which weighed 60 to 75 pounds [each]. Collectively, the collectors' collections caused considerable cockpit crew consternation.

CLIMBING out when out of the corner of my eye I saw something on my left. As I turned to look, I saw a rope dangling above me, just off my left wing tip. Before I could wonder what ropes are doing hanging from the sky, the tow plane showed up, in a steep dive, no more than 25 feet from me. I don't think the pilot saw me, as he almost dove into me. It was impossible for me to see him before, since he came from above and behind me...no time for evasive action...I became worried about the glider that had apparently just been released, and made 90 degree turns to left and right looking for it, and looked up as well as I could, but never located it.

In July 1979, as part of the FAA plan for disseminating the burgeoning safety information, the aviation incidents that don't make the headlines began surfacing in a monthly newsletter entitled *Callback*, named for the notation scribbled on a report when an ASRS processor needed to contact a report's author for more details on an incident. The one-sheet sky-blue bulletin was educational, lively, and eminently readable. NASA worried that it was too informal, but many of the 3,000 readers disagreed via unsolicited letters of approbation. They looked forward to it, they said, because they needed the information and because it was so much fun to read. That sense of fun was provided by its editor, Rex Hardy, an aviation expert of broad background who brought to the job tolerance, humor, a capacity for patient listening, and a desire to educate.

I visited Hardy at his home in Monterey, California, three years after he retired from the editorial chair at age 73. Hardy, who was *Callback*'s guiding spirit for its first 100 issues, was just finishing his book, also titled *Callback*, which was published by Smithsonian Institution Press last year. The snarl of light aircraft practicing landings at nearby Monterey airport punctuated the conversation in his sun-filled study.

I AM reminded of a story of a Southern state copilot who was given a very complicated ATC [Air Traffic Control] clearance at machine gun rate. When Clearance Delivery had finished, the copilot asked for a repeat. The repeat came back at even a faster rate. The copilot, in a Southern drawl, said, "Clearance Delivery, do y'all heah how fast Ah'm talkin'?" "Affirmative, I do; why?" The response was, "That's just about as fast as Ah can write, too. Would y'all please repeat the clearance one moah tahm?"

Unlike most fliers, Hardy gives full

attention to the reminiscences of his peers, though his own are equally interesting. He's got about 14,000 hours in more types of aircraft than he can keep track of. He told me of one mission as pilot of a Navy photo reconnaissance PB4Y-1 (a Navy B-24) in World War II. Hardy and a crew of 11 took off late one afternoon from New Guinea bound for the Japanese-held island of Palau, east of the Philippines. He found the island in the dark, dropped photoflash bombs, took pictures, and, slipping through an eruption of anti-aircraft fire, turned southeast for Manus Island, which boasted a homing device. "Then a big storm hit," he says. "We couldn't get a star sighting, couldn't home in on Manus. The tanks were going dry and I figured on ditching off New Guinea."

At dawn the crew jettisoned guns, ammunition, and empty tanks and sent a coded message for Dumbo, a PBY Catalina rescue amphibian. When it appeared with two P-51 escorts, Hardy glided toward the New Guinea coast, where he spotted a recently captured airstrip. He dragged his PB4Y-1 in on gas fumes with Dumbo waffling along behind and the Mustangs weaving overhead. He'd set a 19-hour, 45-minute endurance record for the PB4Y-1 and garnered a Distinguished Flying Cross. It's safe to assume that years later, when *Callback* chided a pilot for stretching a flight or wandering into a storm, the editor was speaking from the heart.

Hardy got into aviation well before the war, learning to fly while at Stanford in the 1930s. At the same time, he took up photography and caught the eye of a successful new weekly magazine called *Life*. Hardy made three *Life* covers, which to a photographer is like being knighted. In 1940, Hardy's Hollywood work earned him a commission in a Naval photo unit that film director John Ford had assembled to make training films and documentaries. On December 7, 1941, Hardy was on the carrier *Sarato-*

MAYBE minor, but possibly a potential hazard—refueled my aircraft with 35 gallons of 100 octane fuel—even watched it happen. Went inside—came back and out of habit looked in tanks and drained a sample. Imagine my surprise at seeing a pink sample! I was ready to yell and scream, when I realized my eye glasses (brown-rose colored) had changed the color. Suppose I had worn green sunglasses and looked at a clear fuel? Moral: Look at fuel samples without sunglasses.

CENTER, we've just taken a bird strike and are declaring an emergency." The controller...acknowledged the call and, after making radar identification of the aircraft, asked for additional details on the bird strike. "It was a northeast bound chicken hawk," the Navy pilot said. "He was a big ——— too. He hit our canopy head-on at 300 knots." Maintaining his composure, the controller responded, "Roger, and how fast were you going, sir?"

BASED on the haze, I elected to file IFR [instrument flight rules].... Clearance was to climb and maintain 2000 feet etc. My front seat passenger was a non-pilot and very interested in viewing the area. As we closed on 2000 feet he pointed and asked, "Is that the stadium?" I looked long enough to identify the stadium and when I looked back, the altimeter read 2060. I throttled back, lowered the nose, lost about 50 feet, and the windshield was immediately filled with another aircraft. The other plane was at 2000 feet, crossing from my right to my left. It was so close that I could see the color of the pilot's shirt and see that he wore horn-rimmed glasses and a headset. I was also impressed that his plane must have had a very recent paint job. Had I been precise and on my assigned altitude we would have had a mid-air—absolutely no doubt about it.... I certainly am not advocating busting altitudes, but if I hadn't, I wouldn't be here to tell the tale.

ga off San Diego, teaching aircrews to use mapping cameras. Some 2,400 miles to the southwest, the Japanese were attacking Pearl Harbor. "The place was still smoking when we sailed in a few days later," Hardy says.

When the Navy widened a loophole allowing officers with civilian flight time to get pilot training, Hardy broke away from photography. Wearing gold Naval aviator wings, he flew PBYs on Caribbean submarine patrol, then was put back in photo reconnaissance in PB4Y-1s to map Pacific islands marked for invasion. Those missions taught him a lot about flying, safety, and the lack of it.

After the war Hardy was tempted to go for a master's degree in history, but when faced with returning to the disciplines of youth after the sudden adulthood of combat, he changed his mind. "I like intellectuals," he says, "but I get along better with fliers."

He bought two Stearmans and a twin-engine wood and fabric Cessna known as the Bamboo Bomber, flew charters and an air taxi service, and prospered enough to add more airplanes. But by the late 1940s he'd gotten the message: get big or get out. He knew that he wasn't going to get big, so he called a war buddy who'd become a Northrop representative in the southwest Pacific. Hardy got hired by the company and spent eight years as a flight test and utility pilot, working on everything fro the P-61 Black Widow to the Flyin Wing. When the government cancele the latter aircraft, Hardy recalls, "Jack Northrop's heart broke and the fun was

CENTER asked me to confirm squawking 7500 [on the radar transponder] and I confirmed without it reminding me that that was the hijack code. The approach was curious in that we received sort of special handling. There didn't seem to be anybody else on the frequency and everything went very smoothly. Tower asked us to roll out all the way to the end of the long runway, which seemed odd. It was only when I taxied off the runway and was surrounded by a phalanx of vehicles and the whole world was there to greet us and someone asked if I knew the meaning of Code 7500 that it dawned on me what had happened. It was then difficult to convince the authorities that the flight was in no way abnormal. Unfortunately in the papers the next day they correctly spelled my name.

gone. I left and went to Lockheed."

Lockheed needed someone to ferry its executives around the West Coast. "They had plenty of test pilots," Hardy says, "but they all wore orange flightsuits, not right for a corporate plane. I happened to be wearing a necktie, so I was it, chief pilot for what amounted to a small airline just for Lockheed. I had a bunch of pilots under me. Neckties, dark blue suits." He stayed with Lockheed until 1969.

Some 40 years of flying experience made Hardy a natural to help sort through some 60,000 reports during his ASRS tenure. His position as *Callback* editor had clout, but he wielded it with care. The words of warning were free of bombast. The reminders that perfection is necessary but elusive were gentle enough to lure humbling anecdotes out of the prickliest captains. The little sounding board ran the gamut of situations from the sublime to the ridiculous, including those that Hardy simply labeled "Good Grief!"

Hardy is too honest to pretend he's never done a dumb thing himself. In the October 1989 *AOPA Pilot*, a department called "Never Again" featured a story by a veteran pilot who made a short and routine night flight for the umpteenth time and landed at the wrong airport. The abashed author was Hardy.

After he retired in 1987, Hardy kept a column going in *Callback*. It gave him an excuse to keep a foot in the door and keep up friendships with the people he'd worked with for so long. Working on the book had isolated him, and when I talked to him he was glad that such an intensive job was finished and he could again drop in at the office for coffee and doughnuts with the gang.

Today, *Callback*'s readership is estimated at 90,000. The format is still the same as when it began 12 years ago—a legal-size blue sheet with a flip-up back side for easy reading when tacked on a bulletin board—and Rowena Morrison, his editorial successor, has retained Hardy's light tone. Most of the nearly 3,000 reports the ASRS receives every month are from airline pilots, but there are also contributions from controllers, general aviation and military pilots, mechanics, flight attendants, and even passengers.

The database they end up in contains 190,000 anonymous reports that are invaluable to air safety researchers. The ASRS has generated more than 40 technical papers on aviation safety—pilot fatigue, aircrew distractions, and the problems of information processing in the cockpit—and has issued more than 1,200 alerts on everything from confusing taxiway markings to unexpected wake turbulence on landing.

Reflecting on what he's accomplished, Hardy seems a little embarrassed that he's always loved his work and that life has been such fun. It doesn't occur to him that he's earned it by giving so much of himself to the saving of other skins. "It's just that I've been unreasonably lucky," he says. "Always at the right place at the right time."

***MY INSTRUCTOR** felt I was ready for my CFI [certified flight instructor] checkride, so he had me fly with another instructor to find any weak spots.... While I was going through the pre-start checklist (I was in the right seat) he quizzed me about the pressure switch in the nose gear (aircraft was a small retractable gear type). When I indicated that I didn't know how to test it he said, You can test it this way, as he turned the master switch ON and pulled the gear lever to the UP position. In accordance with Murphy's Law, the pressure switch didn't work, and the nose of the aircraft crashed to the pavement.*

***COLD** night at the airport. Captain decided to take a look over the right wing while the catering truck was up at the galley door. When he stuck his head out the galley door he noticed ice cubes on the inboard portion of the wing. When quizzed about the ice cubes, the catering people said that they were throwing extra ice on the ramp and some (two buckets worth) happened to land on the wing. They also said, "It was no problem." Solution: The Captain called ramp service and had them de-ice the right wing. I liked his decision, since the aircraft manufacturer never did ice cube tests on airfoils. If more pilots took precautions as this captain did, we would all have fewer accident reports to read.*

The Crash That Killed Knute Rockne

When Notre Dame's football coach died, he saved us from at least one sin: dangerous airliners.

by Dominick A. Pisano

On the morning of March 31, 1931, Transcontinental and Western Air flight 3, a silver and red Fokker F-10A en route to Los Angeles, was plowing through a leaden sky over southeastern Kansas. It had departed 45 minutes behind schedule because its load of mail had been delivered late, and at 10:22 a.m. the crew contacted a TWA radio station in Wichita to report that they had been forced too low by clouds and were turning back toward Kansas City. At 10:35 they called again to ask for the Wichita weather. The radioman, G.A. O'Reilly, responded that it was clear with ceiling unlimited, and the crew said they would try again to make Wichita. At approximately 10:45 O'Reilly asked if they would get through, and when he got no answer he called again. "Don't know yet, don't know yet," came the reply. It was the last radio contact with the airliner.

A few minutes later, eyewitnesses near Bazaar, Kansas, looked up and saw flight 3 emerging from the clouds and banking as though it were about to land. Then they heard a loud bang as a section of the Fokker's wing separated from the fuselage and fell to earth. The airliner's nose dropped, and the plane dove 1,500 feet to the ground, crashing in a cow pasture owned by Stewart Baker. As it fell, twisting and disintegrating, part of its contents spilled, and five bodies hit the ground at almost the same time the airplane did. Arthur and Edward Baker, Stewart's sons, rode to the crash site on horseback but found no survivors. What they didn't know was that among the victims in the wreckage was none other than Knute Rockne, the famous football coach of Notre Dame.

Rockne had been on his way to Los Angeles to give speeches and advise on the making of a Hollywood film about football. The day before, he had seen his mother in Chicago and then taken a train to Kansas City to meet his morning flight. At the railroad station, Rockne was to have visited briefly with his two sons, Bill and Knute Jr., but they were late, and he missed seeing them by approximately 20 minutes.

UPI/BETTMANN

At 43, Rockne was at the height of his coaching career. The Fighting Irish were a major football dynasty, and his death evoked a huge outpouring of grief. President Herbert Hoover called it a "national loss." Will Rogers said, "We thought it would take a president's death to make a whole nation shake their heads in real sorrow and say, 'Ain't it a shame he's gone?' Well, that's what this country did today, Knute, for you. You died one of our national heroes." Even Charles Lindbergh acknowledged Rockne, saying his character and influence were felt by those far removed from his field.

The aviator could not have known how prophetic that remark was. Through a series of circumstances, the Rockne crash became a milestone in the course of modern aviation. It set in motion a chain of events that hastened the transition from wood to metal in aircraft construction, helped to create a more modern airliner, and revolutionized air travel.

Government and industry had been working to make flying safe for passengers since the airline business began in the late 1920s. When Herbert Hoover had taken charge of the Department of Commerce, the federal agency that in 1926 had been assigned the responsibility to regulate civil aviation, he had realized very quickly that commercial aviation would prosper only if the government took over the licensing of pilots and oversaw the safety of aircraft operations. The Aeronautics Branch had made considerable progress toward this goal under two directors, first William P. MacCracken and then Clarence Young. Because of the efforts of MacCracken and Young,

people were just beginning to perceive flying as a safe way to travel. In 1930 some 417,500 passengers took to the air. While that number was small compared with those who used trains, it was more than double the previous year's 173,000.

Sensing that the Rockne crash might destroy the fragile perception of air travel safety, Clarence Young rushed field representatives to the scene of the accident. The investigators immediately set to work looking for a plausible cause, but over the next few weeks their deliberations would only embarrass the Aeronautics Branch.

Within a week, the investigators came up with three different explanations. The first theory was that Robert Fry, captain of the ill-fated Fokker F-10A, had lost control of the aircraft in turbulence. Then, on April 2, the investigators speculated that ice, which had been found around the wreckage, must have come loose from a propeller hub, struck the propeller, and broken a blade. Vibration from the broken propeller would have exerted a 100,000-pound load on the engine and its mount, breaking the wing from the fuselage. On April 7, this explanation too was dismissed when the propeller in question was dug up intact.

A day or so later, the investigators put forth yet another explanation: the pilot, who knew that the weather had cleared in Wichita, was attempting to get above low-lying clouds. As he did so, ice formed on the aircraft and "possibly rendered inoperative certain of its instruments," causing it to go into "a steep glide." As the pilot tried to pull up, "the change of direction occurred at such unusual rapidity as to build up an enormous load on the wing, which in return brought about the wing failure." That theory too was eventually discarded, and the field investigation, which never reached a firm conclusion, was never again considered in subsequent events.

On May 4, 1931, a little over a month after the crash, the Aeronautics Branch prohibited Fokker F-10s and F-10As from carrying passengers over established domestic air routes. Some 40 aircraft belonging to Pan American Airways, American Airways, and TWA were affected. At that time, the branch's action was unprecedented. Clarence Young, who issued the order, said that it had been prompted by the investigation of the Rockne crash "and developments resulting from that inquiry." Young suggested that the aircraft would not be able to return to service until they had been inspected and overhauled at Fokker factories.

Soon after that, Young issued a statement to the press that read: "The Department of Commerce has requested certain air transport operators who are now using a particular series of tri-motored Fokker airplanes to temporarily suspend the use of them for passenger transport purposes until such time as the department and experts from the Fokker Company may inspect them for present condition of maintenance.... There is no reflection of any kind upon Fokker aircraft or its basic design and original construction. The only point involved is the actual maintenance of the particular ships."

According to the *New York Times*, "The announcement of the department's decision came with a suddenness that left aviation authorities in Washington dazed." What the *Times* and others missed was that the branch was skirting two important issues—the Fokker F-10's suspect wing structure and its reported instability—about which it had significant information long before Rockne's flight. Nick Komons writes in *Bonfires to Beacons*, a history of the Civil Aeronautics Administration, "[B]y the eve of the Rockne crash, the Branch felt it had enough evidence to justify grounding the aircraft immediately."

Although the grounding order makes no mention of the fact, an F-10 wing had been tested extensively by Army and commerce department engineers at Wright Field, Ohio, not long before the order was issued. And concern about the Fokker F-10 had been formally expressed as early as December 16, 1930, some three and a half months before the crash. Dillard Hamilton, a National Parks Airways inspector, wrote to Gilbert G. Budwig, the Aeronautics Branch's

With Rockne as coach, Notre Dame won back-to-back national championships in 1929 and 1930 (left).

The F-10 owed its reputation for safety to its three engines and its legendary designer, Anthony Fokker.

director of air regulation, regarding the F-10's all-wood wings. "The plywood covering checks in very good shape," Hamilton said, "but I always worry about the spars and internal bracing. That is covered up where one cannot check." Hamilton also recounted that a representative from the Fokker factory had suggested adjusting the F-10's ailerons—control surfaces on the wing—in order to "relieve tail heaviness." Hamilton was concerned that the adjustment, which entailed rigging, or the angle of alignment, might cause the pilot to lose control in a turn in bad weather.

Budwig replied that "we are not familiar with the factory recommendation...and do not believe that such rigging will correct tail heaviness." Budwig told Hamilton that "in view of the turning characteristics which you describe it would be advisable to rig the ailerons in the normal manner."

There was yet another indication that there might be something wrong with the F-10: when the Navy twice tested the F-10 for possible military use early in 1931, it rejected the aircraft on both occasions. At the same time the Aeronautics Branch announced the grounding of the aircraft, Rear Admiral William A. Moffett, chief of the Navy Bureau of Aeronautics, made it known that after the first test, at the Anacostia naval air station on January 15, 1931, the trial board had ruled that the F-10 was unstable.

Modifications had been made at the Teterboro, New Jersey factory of the Fokker corporation, and the airplane had been re-tested on April 9 at Anacostia. On April 18 the trial board found that the modifications were "relatively ineffective" and the aircraft was still unstable. On April 21 the Navy notified the Department of War about its tests, and the next day the aircraft was returned to the Fokker plant "for further modification." Moffett asserted that the Navy had notified the Department of Commerce of the results of both tests.

Airline pilots said the F-10's wings vibrated badly, and one did break off Rockne's airplane (right).

The wreckage held only a few clues, but Rockne's death prompted public scrutiny and the grounding of F-10s.

WIDE WORLD PHOTOS

In light of Dillard Hamilton's letter and the Navy's rejections, it is surprising that the Aeronautics Branch did not take action on the F-10 before the Rockne crash. But even more incriminating is that it waited nearly five weeks *after* the crash to do so, even though it had other important evidence. In a memo written to the chief of the branch's inspection service on April 7, 1931, Leonard Jurden, the Aeronautics Branch's supervising inspector based at Kansas City Municipal Airport, said in effect that he thought all the theories the Aeronautics Branch had formulated about the crash were incorrect. Jurden cited the testimony of Paul Johnson, a pilot for National Air Transport, who had taken off from Kansas City 15 minutes after Rockne's flight. Johnson said he had met up with the TWA Fokker over Emporia, Kansas, a short distance from the scene of the accident. Johnson reported that flying conditions were very bad and that he had been forced to fly close to the ground. Jurden believed that the Fokker carrying Rockne had experienced the same troublesome weather.

Jurden's memo also cited widespread rumors that the Fokker F-10's wings tended to flutter or vibrate in bumpy air. Johnson's report estimated that pilots encountered turbulence on approximately 16 to 20 percent of all trips over the Kansas City-Los Angeles route. Jurden calculated that Rockne's airplane had been subjected in its lifetime to more than 300 hours of "continuous flexing" of its wing because of air turbulence; its wings would thus have been weakened and susceptible to failure under severe stress. He speculated that the aircraft had been making a sharp turn, that its wings began to vibrate as it ran into turbulence, and that part of the wing covering loosened "at the point where all the flexing of the wing had been centered," further weakening the wing. This "would put greater force on the remaining part [of the wing] and possibly cause it to snap off, throwing the ship upside down, in which position it hit," Jurden wrote.

Jurden substantiated his conjecture by examining the wreckage for himself. From his inspection of the wing parts, he surmised "that the wing broke off upwards, under compression." He also found that the wing spars, which were made of spruce and birch, showed "very definite compression breaks as well as poor gluing." Furthermore, he observed the "peculiar glue conditions[,] particularly the upper and lower laminated portions of the box spars. Some places the glued joints broke loose very clean, showing no cohesion of the pieces of wood. Other places showed that the glue joints were satisfactory."

Jurden corroborated the rumors of wing vibration the following day in an April 8 memo to Gilbert Budwig, asserting that some TWA pilots were afraid to fly the F-10 because its wingtips had a tendency to flex in turbulent air. One of the pilots told Jurden that he had "personally encountered this flutter condition every time he allowed the plane to gain speed in bumpy air," that the "flutter was very rapid, the tip of the wing travelling up and down over a six to eight inch travel," and that the vibrations "would not dampen out of their own accord but would increase if left alone." The only way to stop the flutter was to throttle down the engines. The pilot added that the flexing was "not absorbed along the entire wing but is centered at one point"—the point at which the wing of the airliner that carried Rockne to his death had broken off.

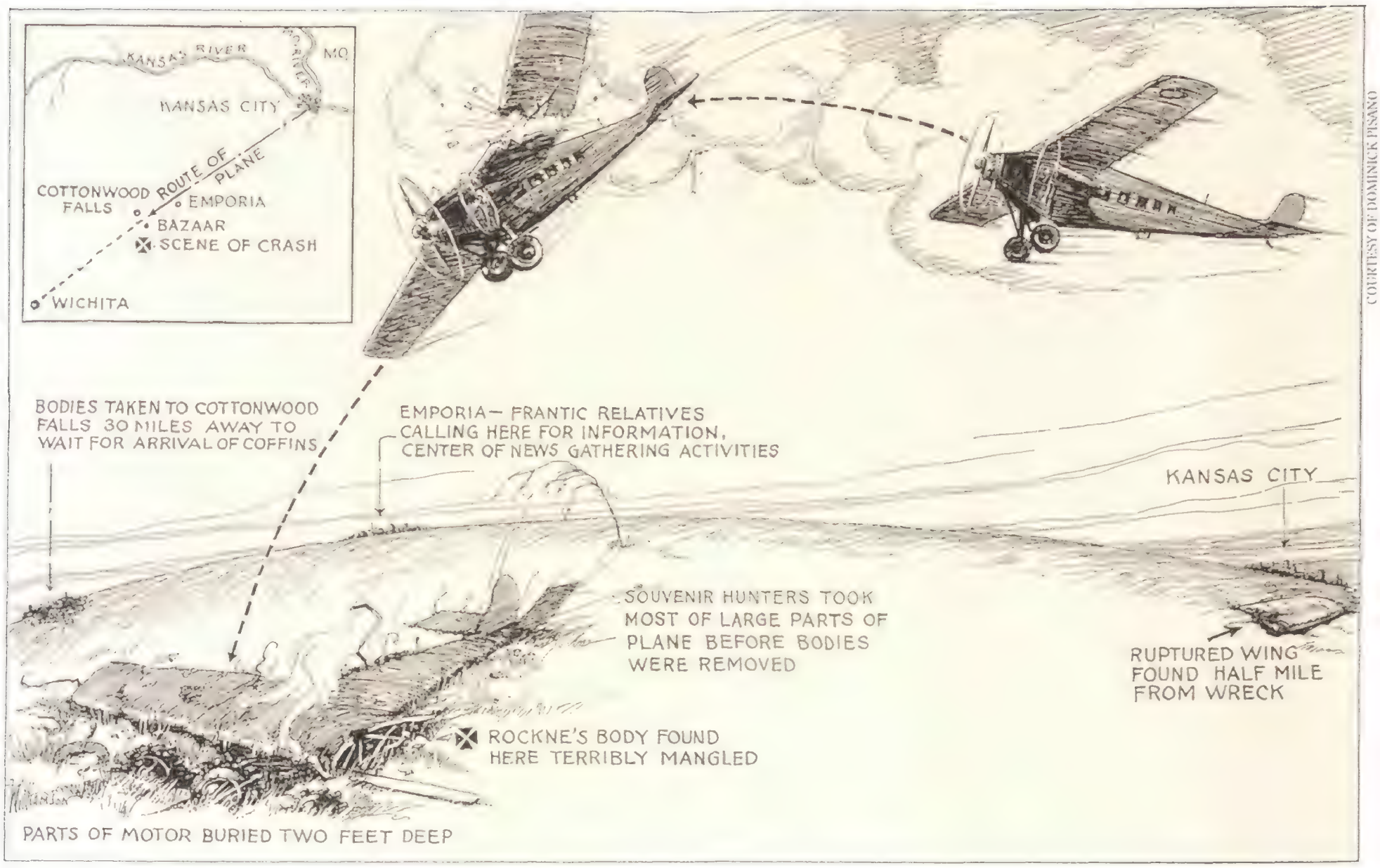
Fokker F-10A Super Trimotor

At top speed, three 425-horsepower Pratt & Whitney Wasp engines drove the F-10A and its payload of 12 passengers at the stately pace of 154 mph. That its wing was entirely wooden was no surprise; wood structure had a long tradition in airplanes, and the plywood skin could be shaped to form a smooth surface.

In his April 7 memo, Jurden said he believed that when pilot Robert Fry had run into turbulence and the wing had begun to flutter, he had throttled down the engines, causing them to backfire, which might account for the loud noise witnesses heard just before the airplane hit the ground. Jurden also reported that "the propellers show that they were not revolving very rapidly, if at all, at the time of the impact." This could mean that Fry had reduced power in an attempt to dampen the wing vibrations. But he probably could not stop the flutter, and the wing, fatigued by hours of continuous flexing, finally snapped off.

Another TWA pilot Jurden interviewed said that while learning to fly the Fokker F-10, "none of the pilots would allow the plane to exceed more than cruising speed being afraid of the roof [the wing was overhead] coming off." Another told Jurden that on one flight the aileron began to vibrate so badly that it tore loose from its moorings on the wing, and on another occasion vibration shook the control wheel of the aircraft right out of the pilot's hands.

Jurden's letter went on to explain to Budwig that "all the pilots either knew from personal experience of this condition or by hearsay," but that, according to Jurden's source, "the pilots had never discussed this condition because they were afraid that they would be fired and black-listed over all operating lines."



COURTESY OF DOMINICK PISANO

Although we will never know exactly why Rockne's airplane crashed, Jurden's hypothesis—that the Fokker F-10 had encountered uncontrollable wing flutter in turbulent air—is probably correct. Others who have analyzed the Rockne crash have cited moisture and wood rot inside the Fokker's wings as contributing factors. But Jurden's unequivocal finding of compression breaks in the wing spars and his conclusion that the wing covering had separated because of faulty gluing seem conclusive.

Why the Aeronautics Branch, in the face of all these indications, did not move earlier to take corrective action or make the results of Jurden's investigation public remains a mystery. But some speculation is in order.

The Rockne crash may be one of the first of many instances of bureaucratic reluctance to take action until an accident makes it necessary. The collision of a United Air Lines DC-7 and a TWA Super Constellation over the Grand Canyon in 1956 killed 128 passengers and crew, resulting in better long-range radar equipment and air traffic control procedures as well as the formation of an independent Federal Aviation Agency. In 1979, a Douglas DC-10 taking off from O'Hare Airport in Chicago crashed when one of its wing-mounted engines tore loose; as a result, the DC-10 fleet was temporarily grounded, the airplane's design was questioned, and American Airlines' method for removing engines from their mounts was faulted.

Another factor that may have contributed to the Rockne crash is the comfortable relationship that had developed between the branch and the aviation industry as a result of the commerce department's desire to boost civil aviation. Fearing the industry's wrath, the branch avoided enforcing safety regulations or publicizing the results of accident investigations. Nick Komons relates in *Bonfires to Beacons* that in 1926 and 1927, the branch "issued a few full-scale reports on major air disasters. Pilots, aircraft, and air carriers were identified and the probable cause of the accident was attributed in each case." The industry was displeased, though, and the commerce department soon put a stop to the practice. "A tight lid of security was placed on all other particulars," Komons writes. "In this way, the cause of a specific accident could never be traced by the public, the Congress, or interested parties."

Had Knute Rockne not been a casualty, the Aeronautics Branch in all likelihood would have kept a "tight lid of security" on its previous discoveries about the Fokker F-10's instability and on the crash. After making its decision to disclose all information on the accident, the branch went overboard and put forth not one but three hypotheses. In so doing, it may have been attempting to cover up its knowledge of the aircraft's stability problems, especially the tendency of its wings to flutter. The Navy's report on the aircraft's instability and the TWA pilots' condemnation of the F-10's wings were so damaging that the branch had no choice but to ground the aircraft.

After the May 4 passenger ban, Anthony Fokker and his colleagues met with Young and other branch personnel for three days of contentious discussion. Fokker insisted that

Reports from the scene were sensationalized in the press, which avoided facts it didn't understand.

"the condition of the planes used on commercial lines is a responsibility of the owner and not of the builder" and asserted that "the United States will not see Fokker planes blown from the sky merely by the error of maintenance of one operator. I am battling for my reputation." He had contended from the beginning that Rockne's flight "should not have been undertaken in existing weather conditions" and that the pilot had not had enough experience in instrument flying. But Fokker lost his heated arguments with Young, and the aircraft remained grounded.

On May 7 an agreement was reached. The branch announced that the corrective "program involves certain reconditioning and maintenance items which concern the wing and a modification of the aileron design," which would "correct an aerodynamic characteristic as well as to give effect to more recently accepted practices." This meant that the Fokker company, the Aeronautics Branch, and the airlines that flew the F-10 would have to inspect inside the aircraft's wings and install a counterbalance weight on the ailerons. The aileron counterbalance was undoubtedly related to the factory's suggested aileron adjustment that Dillard Hamilton had mentioned in his letter and was intended to correct the flutter TWA pilots had described to Leonard Jurden.

After the initial inspection and modification had been made and the Aeronautics Branch had allowed the aircraft back into service, all of the airlines would have to make stringent periodic inspections of their F-10s. Mechanics would have to remove each wing's plywood skin, inspect inside, and then reinstall the skin—a difficult and costly procedure.

Despite the grounding and the steps taken to prevent further accidents, the public and the press were still bewildered about the cause of the Rockne crash. A *New York Times* editorial complained that "both the Department of Commerce and Mr. Fokker might have been more explicit in their authorized explanations and thus removed doubts about the soundness of the Fokker design." Clarence Young reiterated to the press that the order suspending the Fokkers "was not due to the design but concerned maintenance of the ships, particularly as to the wings," but the branch was not being entirely honest. By ordering the airlines to shore up maintenance procedures and modify the F-10's ailerons, the branch could hedge about the Fokker's inherent structural deficiencies, cover up its complicity in the Rockne crash and its bungling of the investigation, and save itself from more embarrassment.

Government investigators' muddled explanations seemed directed at covering up the F-10's design flaws.

UPI/BETTMANN

The majority of the F-10s were returned to service within a month, but the construction of the wood-wing craft had been called into question, and for Anthony Fokker, the famous designer of World War I fighters, it was the end of a career in the United States. Until the Rockne crash, Fokker aircraft had been regarded as the safest in the world; now they were tainted. Fokker was later "retired" as director of engineering for the Fokker Aircraft Corporation by General Motors, Fokker's U.S. parent company; eventually he returned to Europe.

Jack Frye, TWA's vice president in charge of operations, was furious about the Aeronautics Branch's decision, which threatened to put him out of business, and he knew he had to find another airplane. He went first to Boeing in the hope of ordering that company's brand-new 247, a streamlined, aluminum alloy aircraft that incorporated many advanced design features. But Boeing refused him because it was building its initial run of sixty 247s exclusively for United Air Lines, a sister company controlled by the United Aircraft and Transport conglomerate. Frye was told to come back in two years, after Boeing had completed United's order. Had Boeing been able to provide the airplane Frye wanted, the 247 might have remained the leader among airliners for several years longer than it did, but when Boeing delayed, Frye went elsewhere.

On August 2, 1932, nearly a year and a half after the Rockne crash, Frye wrote a letter to a number of aircraft manufacturers requesting "ten or more trimotored transport planes." Donald Douglas, whose Santa Monica, California company was one of the smallest in the United States to be contacted by TWA, was intrigued by Frye's letter. After some preliminary studies, two of Douglas' engineers, James H. "Dutch" Kindelberger and Arthur Raymond, concluded that Frye's requirements could be met by a twin-engine aircraft, which they called the DC-1, for Douglas Commercial number one.

On September 20, 1932, Douglas got the contract from TWA for a single test aircraft and an option to purchase as many as 60 more. The all-metal DC-1, only one of which was built, eventually went into production as the DC-2. By 1935 Douglas Aircraft had extended the design even further to produce the revolutionary DC-3, the first truly modern airliner and the first commercial aircraft to make a profit by carrying passengers alone.

Undoubtedly, had the Rockne crash not occurred, a modern airliner like the DC-3 would have been produced in due time, but destiny intervened to speed its development. Ironically, Rockne had once predicted that "two of the improvements which will no doubt make remarkable advances in the next ten years are aviation and television radio." He could not have known how instrumental he would be in bringing the first prediction to life.

Cosmic Time Travel: A Scientific Odyssey *by Barry Parker, Ph.D. Plenum Press, 1991. 308 pp., b&w photos and illustrations, $24.50 (hardbound).*

Time travel was pure fantasy until the early days of this century. Then Albert Einstein demonstrated mathematically that time can be manipulated, and others began looking into the possibilities: cosmologists, astronomers, mathematicians, physicists, philosophers.

Fiction writers were a long time catching up. But eventually, the loss of causality in time travel—the option to violate or even reverse cause and effect, shoot Adolf Hitler, rescue Jesus of Nazareth—tempted writers who work in that domain of logic and reason, science fiction, to play games of logic and reason, to devise time *machines*, in the tradition of H.G. Wells.

Author Barry Parker, a professor of physics and astronomy at Idaho State University, follows another tradition here. Don't mistake his book for fiction; the closest he comes is a mention of astronomer Carl Sagan's science fiction novel *Contact*. It's there because Sagan, in seeking to design a scientifically plausible transgalactic transport system for his book, turned to black hole expert Kip Thorne of the California Institute of Technology for advice. *Cosmic Time Travel* is a text on esoteric physics, emphasizing interstellar travel and aimed at the general public. Yes, the book concentrates on time travel, but only because cracking lightspeed, necessary for truly long space voyages, inevitably makes time travel possible.

Great names of mathematics and astrophysics and modern geometry move through the book: Einstein, Karl Schwarzschild, Herman Minkowski, Roy Kerr, Stephen Hawking, Richard Feynman. The path leads through quantum mechanics, X-ray and infrared astronomy, primordial black holes and the black holes at the cores of galaxies, space and time merged and curved in strange geometries. *Cosmic Time Travel* is rich in

the ideas that shape the frontiers of today's physics, ideas that barely touched the world of science fiction until the last few decades.

Every science fiction writer needs this book. We need to understand what we write about; we don't like looking like idiots. Few of us will shape time machines to match what we find here, but at least we'll know what rules we're violating.

Does Parker give us a time machine? Yes...in a way. Parker's trail through physics builds nicely to a variety of transport systems. There's mathematician Frank Tipler's rotating cylinder (a working time machine, but infinitely long) as modified by writer John Gribbon (finite now, but still as massive as the sun). To see it in action you need Poul Anderson's science fiction novel *The Avatar*.

Parker also describes the transport system defined in Sagan's *Contact* and shows that it can be simplified...maybe. Ultimately it becomes a wormhole (an entirely respectable entity in modern physics) through space, or more accurately space-time, with one moveable end. The hole may be lined with "exotic matter" (hypothetical stuff, not very respectable) to keep it from collapsing. Or you can square off the silhouette of the wormhole, leaving edges but no curvature. To travel in time, then, you must accelerate its moveable end to near the speed of light or hold it near a neutron star. The system is a freeway or railroad, therefore, rather than a car or train. Because you can't go where it isn't, you'll never visit a time before you built it.

While these passageways through time may be theoretically possible, the best Parker can do with current physics leaves them still damn difficult to build. After somehow summoning up a wormhole and lining it with matter that may or may not have objective existence (without the wormhole meanwhile closing in on the engineers), you must retrieve the endpoint and move it where you like through tides that would rip a proton apart. Or you might build a cylinder 100 kilometers long and 10 kilometers in radius with as much mass as our sun, using materials hellishly dense and rigid enough to retain the cylindrical shape against gravity and stand up to the next step: spinning it at better than half the speed of light.

Why did you want a time machine? To repair the past, wasn't it? To unmake history's mistakes, or even your own? But it's never possible to stop with one change. A time machine would give you god-like powers...you, or someone else.

Parker speculates that civilizations ahead of ours may already have done the work. But though a time machine may endow you with god-like powers, you need god-like powers to make one. You can't use a time machine before you've built one; you have to become god-like first.

So. Tourists and conquerors invading Los Angeles from the next century are still fantasy. I, for one, am much relieved.

—Larry Niven is the au thor of many science fiction novels and short stories, including the Hugo and Nebula Award-winning Ringworld.

The Harvest of Desert Storm

In the days before and after last winter's war in the Persian Gulf, a lesser battle has been brewing on bookstore shelves, as a flurry of books and videos vie for consumers' dollars.

It's a safe bet that any book with "Desert Shield" in its title was probably among the first to appear. Prolific photojournalists Eric Micheletti and Yves Debay were quick to the publishing front with **Operation Desert Shield: The First 90 Days** *(Windrow & Greene, Europa Militaria No. 7, $15.95, paperback; December 1990)*, a book heavy in photographs and light in text about the military buildup in Saudi Arabia. GDW's **Desert Shield Fact Book** *(GDW [Games Designers' Workshop], $10, paperback; January 1991)*, a compendium of weapons, equipment, troops, and tactics for those at home watching Arthur Kent on television, comes with a jet navigation chart of the battle area (and the warning that it "not be used for navigation of aircraft"). Pre-war activities receive a more polished treatment in Robert F. Dorr's **Desert Shield: The Build-up: The Complete Story** *(Motorbooks International, $12.95, paperback; February 1991)*, which contains a final chapter entitled "War?" By the time the book made it into print, that question had already been answered.

Micheletti and Debay were early out of the post-war gate as well with their book **Victory: Desert Storm** *(Windrow & Greene, $17.95, paperback; April 1991)*. A photo book sticking exclusively to the allied forces and their weapons, *Victory* strikes a consistently heroic note. Though its photographs are not posed, they aren't true candids either, at least in the sense of revealing anything fleeting or surprising about the combatants. The big payoff is the detailed documentation of the war's paraphernalia: weapons, vehicles, and uniforms.

Books spotlighting the hardware of war include **Desert Storm: The Weapons of War** by Elliot Brenner, William Harwood, and the editors of UPI *(Crown, $9, paperback; February 1991)* and **Weapons of Desert Storm** *(Signet Special, $7.95, paperback; September 1991)*, each of which gives a broad overview of the weapons, including tanks, missiles, and ships as well as the many aircraft.

In the same vein is Royal Air Force Tornado pilot Ian Black's **Desert Fist: Allied Airpower for Desert Storm: A Pilot's View** *(Motorbooks International, $17.95, paperback; June 1991)*, a photo book showing the myriad aircraft that waged war in the Gulf. Since the photographs were taken during the buildup, with the majority shot on the ground at Saudi airbases, there is a certain sameness to the images. The best picture, in fact, is not of a warplane but of a DC-3, windows broken and tires deflated, rusting at a Saudi airfield.

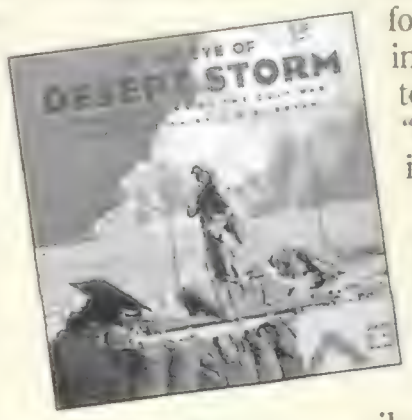
Similar books include Eric Micheletti's **Air War Over the Gulf** *(Windrow & Greene, Europa Militaria No. 8, $15.95, paperback; April 1991)*, a guidebook to the aircraft used in the war, **The Fury of Desert Storm: The Air Campaign** by Bert Kinzey *(Tab Books, $16.95, paperback; August 1991)*, which considers air strategy as well as hardware, and **Air Power: The Coalition and Iraqi Air Forces** by Roy Braybrook *(Osprey Military, $11.95, paperback; September 1991)*, which also focuses on air strategy and rewards the reader with a lusty display of aircraft nose art. What's striking about this group of books is that though they exalt the success of the air campaign, they show us very little photographic evidence of it. These books give the impression that military aircraft do little more than pose prettily at airfields or arc majestically through the sky. Although the photos in **Desert Storm Air War** *(Motorbooks International, $12.95, paperback; December 1991)* were not available at the time of review, author Robert F. Dorr seems to be trying a different tack in the text by using the words of the men and women of the armed forces, from interviews, letters, and diaries, to personalize his telling of the air war story.

The books likely to prove the most popular are those that attempt to cover the war in a more well-rounded fashion, liberally mixing large-format color photographs with brief, digestible histories and analyses of the entire conflict, and lots of maps, diagrams, and information boxes. One of the most visible and best publicized of these is Cable News Network's **War in the Gulf** *(Turner Publishing, Inc., $19.95, paperback, $29.95, hardbound; June 1991)*. It includes a plethora of colorful pictures, a readable if fairly superficial text by Thomas B. Allen, F. Clifton Berry, and Norman Polmar, and, naturally, some CNN self-congratulation. Following the same format are **Desert Storm: The War in the Persian Gulf** by the editors of *Time* magazine *(Time Warner Publishing Inc., distributed by Little, Brown, $19.95, hardbound; May 1991)* and **Desert Storm,** from the editors of *Military History* magazine *(Empire Press, $34.95, hardbound; August 1991)*.

Triumph in the Desert by Peter David *(Random House, $25, hardbound; May 1991)* mixes up the formula a bit by including a number of watercolor paintings among the photos. **Witness to War** by the staff of the *Los Angeles Times (Los Angeles Times, $16.95, paperback; May 1991)* reprints every front page the newspaper ran during the 43 days of the campaign. Compensating for that somewhat self-serving

selection are some useful almanac-style lists, such as a rundown of the Coalition countries, each country's specific contributions, the chief weapons used in the conflict, the 12 resolutions the U.N. Security Council adopted in the early days of the invasion, and the names of the U.S. casualties, along with their ages and hometowns. Individually, each of these books serves as a quick overview of the war; taken together, they will give a reader a strong sense of déjà vu.

In the Eye of Desert Storm: Photographers of the Gulf War, text by C.D.B. Bryan and Glenn Albin *(Harry N. Abrams, Inc., $39.95, hardbound, $24.95, paperback; July 1991)*, is a photo book with a grittier vision. The pictures, all taken by photographers with the Sygma photo agency, reveal the war's human faces: startlingly similar portraits of Norman Schwarzkopf and Saddam Hussein; an image of starving Kurds flocking to a Sikorsky Super Jolly Green Giant helicopter bearing relief supplies. The book's depictions of civilians and families serve to remind readers that beyond tactics and hardware, the war was also a source of lingering sorrow and misery.



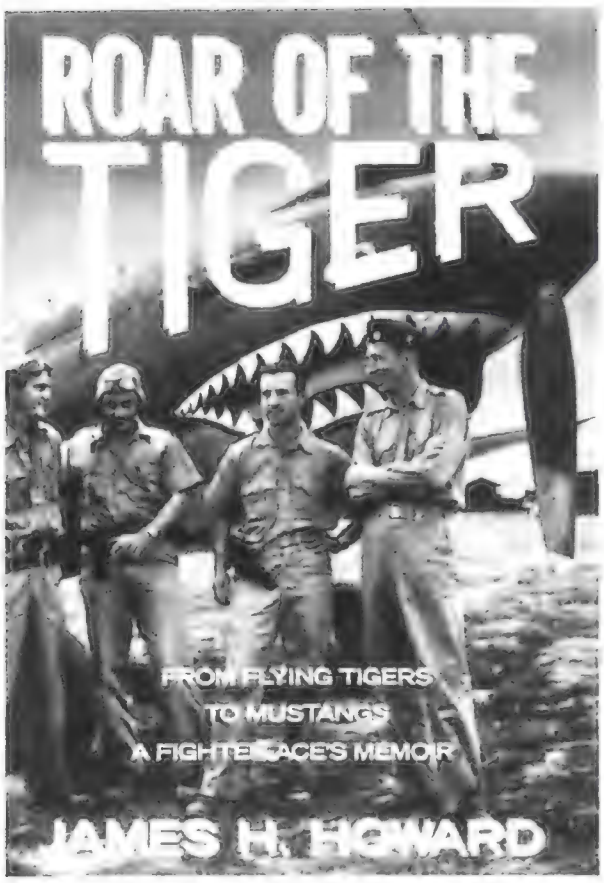
If you've had it up to here with yellow ribbons, you'll probably enjoy reading Martin Yant's **Desert Mirage: The True Story of the Gulf War** *(Prometheus Books, $19.95, hardbound; September 1991)*. As Senator John Glenn grandly understates in the foreword, "it surely is not a book that will please everyone." Yant argues that U.S. actions in the Gulf war were by turns misguided, sadistic, and destructive to world order, new or otherwise. He does so mainly by accumulating newspaper reports and columns critical of the war or at odds with the official version of it. Like the convincing *Chicago Tribune* piece he quotes about the "manifest deficiencies" of the Iraqi army, the articles question the necessity for the loss of hundreds of thousands of lives.

A book less likely to rile students of military operations is Major James Blackwell's **Thunder in the Desert: The Strategy and Tactics of the Gulf War** *(Bantam, $12.50, paperback; September 1991)*. Written from Blackwell's perch at CNN as the network's military affairs analyst, *Thunder* really gets rolling at the point when the tanks do; the air war is the lesser part of his treatment. The book is more a detailed record of the war we all watched than a fresh, behind-the-scenes view that might be expected in the aftermath from an analyst like Blackwell.

Military analyst Norman Friedman's book **Desert Victory: The War for Kuwait** *(Naval Institute Press, $24.95, hardbound; August 1991)* expertly picks up where Blackwell's leaves off. Though its scholarly, information-laden style makes it less entertaining reading than those books intended for a wider audience, Friedman's impressive grasp of tactics and technology brings the "how" and "why" of every military maneuver into clear focus.

Among aviation-related Gulf war videos recently released is **Eagles Over the Gulf: Desert Storm, The Original Air Footage** (*Blue Heron Films [502-581-1900], $14.95; May 1991)*, in which pilots narrate combat sorties: we see F-18s being slam-dunked onto carriers, F-16s tiptoeing down desert runways, F-117s skulking along the horizon at dusk. There's lots of snazzy footage—and a sappy song at the end. Strictly for hardcore enthusiasts is Blue Heron Films' **Eagles Over the Gulf: Desert Storm, The Gun Camera Footage** *($19.95; September 1991)*, which includes a backseat ride in an F-16 on a bombing mission as filmed by an excitable cameraman. (A related audio tape from Blue Heron, **Eagles Over the Gulf: Desert Storm, The Pilots' Stories** *[$12; September 1991]*, features more in-depth pilot interviews as well as cockpit recordings, including a series of calls from an F-16 pilot who was forced to eject over Iraq.) Part of a four-tape series on the war, **Desert Storm: The Air Assault** *(Video Ordnance [212-575-0550], $24.95 including postage; February 1991)* contains tutorial-quality footage, with lots of interviews with desk-bound brass and specialists. The film's highlight is the radio transmissions of the gleeful Saudi F-15 pilot who bagged two Mirage F-1s on one outing.

Stay tuned; there's undoubtedly more to come.



Roar of the Tiger: From Flying Tigers to Mustangs, A Fighter Ace's Memoir
by James H. Howard. Orion Books, 1991. 310 pp., b&w photos, $22 (hardbound).

On January 11, 1944, a lone P-51 came to the rescue of a bomber formation beset by some 30 German fighters. When asked why he had risked his life against such odds, the gangling Mustang pilot charmed the home front by answering: "I seen my duty and I done it."

Jim Howard won the Congressional Medal of Honor for that exploit. Now, in this memoir of World War II, he tells how he became a fighter pilot in the peacetime Navy, then resigned his commission in the spring of 1941 to join Claire Chennault's American Volunteer Group to defend China from Japanese bombers. His story of the Flying Tigers is pretty much the Authorized Version, as told in dozens of books over the years. Still, AVG buffs will be fascinated by his stories of intramural jealousies in that heroic band of mercenaries—and by his suggestion that it was those men, not their commander, who devised the AVG's tactics for beating the nimble Japanese, which no other Allied air unit had managed to do in the first six months of the Pacific war.

When the Flying Tigers disbanded in July 1942, Howard was among the vast majority who went home rather than join the U.S. Army in China. He eventually accepted an Army commission, in time reaching England as a major commanding the 356th Squadron of the 354th Fighter

Group, the first to be equipped with the redoubtable Mustang. (Perhaps one reason for the Flying Tigers' immortality is the piquance of their name, in contrast to the mind-numbing numerical designations of Army units.) While escorting bombers over Germany, Howard achieved the rare distinction of becoming an ace in both the European and Asian theaters of the war.

Roar of the Tiger has many humble touches, of a kind generally overlooked by those trained as fighters instead of writers. Howard remembers the weather, the difficulty of targeting an airplane moving on a heading different from that of the attacker, and the "red ass" syndrome suffered by a pilot after six hours of sitting on a parachute and an uninflated dinghy.

There are the mandatory passages about the thudding of 50-caliber guns and the terrible beauty of tracer bullets crossing in air. But for those who groove on such images, Howard ends his memoir on a cautionary note: "war," he reminds us, "is not the feast of excitement and reward that it might appear to young combat fliers, but a series of cruel episodes that do not all end in glory."

—Daniel Ford is the author of Flying Tigers: Claire Chennault and the American Volunteer Group, *recently published by the Smithsonian Institution Press.*

Where the Galaxies Are, *8-minute video with explanatory booklet, distributed by the Astronomical Society of the Pacific (415-337-1100), $32.95.*

Astrophysicist Margaret Geller has recently been pursuing ways to interest lay audiences in her fascinating and difficult field (see "Surveyor of the Universe," August/September 1991). This video represents Geller's first major effort to explain in a popular genre her ongoing Redshift Survey of the galaxies. Computer graphics, which are the film's primary graphic device, beautifully animate the curious bubble-like clustering of galaxies that Geller and her colleagues at the Harvard-Smithsonian Center for Astrophysics discovered in 1985. The narrative, however, strains so incessantly to attain a note of lyricism that it ends up muddling the science, rather than clarifying it.

Rising Above It: An Autobiography *by Edna Gardner Whyte with Ann L. Cooper. Orion Books, 1991. 256 pp., b&w photos, $20 (hardbound).*

Through most of *Rising Above It: An Autobiography,* Edna Gardner Whyte is mad. She is mad at men, "damnable men who were at aviation's helm and stood in [my] way." From the day in 1927 when she took her first lesson in a Travel Air and was "mocked" by a swaggering male instructor, "men were my nemesis," she says. "One bastard after another crossed paths and swords with me."

Because she was a woman, she contends, she never got the airline job she longed for, or flew the mail, or became a Navy pilot (she was a Navy nurse). She had to put up with remarks like "you should be home doing diapers and dishes" and the more insidious "you fly like a man," and Whyte was once almost denied prize money when she won a pylon race against shocked male contestants.

Whyte did have plenty to be mad about, but in her passion to succeed in aviation she could be accused of considerable arrogance herself. When her kindly (male) mentor, Guerd Brockman, was slow to push her aerial exploits (he considered it "bragging"), she became furious and accused him of holding her down. "Publicity is the fuel for the fire of fame," she informed him (or so Ann L. Cooper, the "as told to" co-author of the book, writes; it's hard to know who is responsible for the often-stilted voice that emerges). After another man gave her a job teaching at his flight school, she started a school of her own at the same airport and took many of his students with her. Her second husband called her "driven." "I ached for a chance at fame," she explains. "All I wanted was a chance to *be* somebody."

She did become somebody, winning 26 aviation trophies, including several in closed-course racing, her favorite event. Despite her grievances, she does seem to have had a lot of fun flying the great old airplanes and meeting the famous pilots of flight's golden age, and her fierce love of aviation gives the book a badly needed lift. Unlike many of the others, she survived the golden age, and in her late 60s she started her own airport. Now in her late 80s, she is still flying, racing...and remembering.

—A freelance writer based in New York, Mariana Gosnell is the author of a book on small airports, soon to be published by Knopf.

Credits

By Airship to America. A retired research geneticist, Roger Pilkington is an avid sailor and author of some 20 books on boating.

Out for a Spin. Ron Dick is a contributing editor of *Air & Space/ Smithsonian.*

The Drug Fight. Carl Posey flew with the Red Devils while doing research for his latest novel, *Bushmaster Falls.*

Shoot for the Moon. Andrew Chaikin writes frequently about astronomy and space exploration. He looks forward to visiting Moonbase Alpha and plans to bring his guitar.

Trouble in Paradise. Roger H. Ressmeyer is the author and photographer of *Space Places* (Collins, San Francisco, 1990), a book documenting 5,000 years of space exploration. His photographs have appeared in *Life, Time,* and *Newsweek.* He lives in Sag Harbor, New York.

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The Biggest Little Airplanes in Texas. Ed Regis, author of *Great Mambo Chicken and the Transhuman Condition* (Addison-Wesley, 1990), is at work on a book on nanotechnology. He wrote "The Rocket Ranch Gang" for the February/March 1991 issue of *Air & Space/Smithsonian.*

The Spies in Space. Jeffrey T. Richelson, an author and consultant based in the Washington, D.C. area, has written several books and articles about intelligence and space activities. His most recent book is *America's Secret Eyes in Space: The U.S. Keyhole Spy Satellite Program* (Harper & Row, 1990).

Further reading: *Deep Black: Space Espionage and National Security,* William E. Burrows, Random House, 1986.

True Confessions. Edwards Park is a contributing editor of *Air & Space/ Smithsonian.*

The Crash That Killed Knute Rockne. Dominick A. Pisano is a curator of aeronautics at the National Air and Space Museum.

Digging for a Buried Star. David Savold is an associate editor at *Air & Space/ Smithsonian.*

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Calendar

November 16–December 28
"The Staten Collection: Pictures from the USS *Saratoga*." Kalamazoo Aviation History Museum, Kalamazoo, MI, (616) 382-6555.

December 3–6
"Prelude to Pearl Harbor: The Interwar Years," an international symposium. Midland, TX, (915) 563-1000.

December 7 & 8
Pearl Harbor Memorial Service. Kalamazoo Aviation History Museum, Kalamazoo, MI, (616) 382-6555.

December 7–January 5
"Steichen and His Men: A Photographic Portrait of World War II." Smithsonian Traveling Exhibition. Ohio Historical Society, Columbus, OH, (614) 297-2439.

December 28–30
Warbird Fly-In. Reilly Aviation Museum, Kissimmee Municipal Airport, Kissimmee, FL, (407) 933-1942.

December 28–February 2
"The View From Space: American Astronaut Photography, 1962–72." Museum in the Community, Scott Depot, WV, (304) 757-2509.

January
"Blueprint for Space: Science Fiction to Science Fact," an exhibition. IBM Gallery of Science and Art, New York, NY, (212) 745-6100.

January 1
Sno'Fly: The First Kite Fly of the Year. Prairie View Park, Kalamazoo County, MI, (616) 383-8778.

January 16 & 17
Aerospace Education Leadership Symposium. This year's theme is general aviation. U.S. Air Force Academy, Colorado Springs, CO, (303) 676-3082.

January 19
Open Cockpit Sunday. Aircraft open for viewing include an F-4D Phantom II, a P-47 Thunderbolt, and a UH-1 helicopter. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (203) 623-3305.

January 27
The Space Frontier Society Symposium. IBM Gallery of Science and Art, New York, NY, (212) 745-6100.

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Awards:
Guggenheim: predoctoral, $13,000; postdoctoral $21,000. **Verville:** 12-month fellowship: $26,000

Contact:
National Air and Space Museum [illegible]
[illegible]th St. & Independence Ave., SW
[illegible]

Deadlines:
[illegible]

"The Satellite Sky" Update/27

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2156 9-19-91 PL
- Cosmos 2163 10-9-91 TT
- Cosmos 2164 10-10-91 PL
- Foton 4 10-4-91 PL
- Progress M-9 8-20-91 TT
- Soyuz TM-13 10-2-91 TT

300 to 630 MILES

- Cosmos 2154 8-22-91 PL
- IRS-1B 8-29-91 TT
- Solar-A 8-30-91 KAG
- UARS 9-12-91 KSC

630 to 1,250 MILES

- Cosmos 2157-62 9-28-91 PL
- Meteor 3-5 8-15-91 PL

21,750 to 22,370 MILES

- Anik E-1 9-26-91 KOU
- BS-3B 8-25-91 TAN
- Cosmos 2155 9-13-91 TT
- Intelsat VI-F5 8-14-91 KOU

DATA: SAUNDERS KRAMER

Deletion

90 to 300 MILES

Soyuz TM-12 down 10-10-91

Inoperative but still in orbit

21,750 to 22,370 MILES

Raduga 10	Raduga 15	Raduga 17
Raduga 14	Raduga 16	Raduga 18

Launched but not in orbit

90 to 300 MILES

Resurs F-13 USSR earth sensors	8-21-91	down 9-20-91

300 to 630 MILES

STS-48 US research	9-12-91	down 9-18-91

Forecast

In the Wings...

Air Guard Rescue. Both in times of war and times of peace, the 129th California Air Rescue Squadron sees to it that downed aviators are saved.

Civvies in Jets. Retired military jets—with the weapons removed—are some of the hottest toys around.

Global Positioning System. Civilians are being denied the most accurate GPS signal. Why the fuss over 275 feet?

Who Shot Down Yamamoto? Two P-38 pilots each claimed to have downed the airplane carrying the Japanese admiral who planned the Pearl Harbor attack. Nearly 50 years later, some people still argue over who gets the credit.

By the Satellite's Green Glare. Or: Come to Aruba When the Barium Blooms. And learn something about the workings of the upper atmosphere.

Radioactive Tankful. For long-distance space travel, nuclear may be the only way to go. How serious are the drawbacks?

JOHN HEINLY

Digging for a Buried Star

It was sometimes hard to find a cowboy in the northern part of the Arizona Territory. In the late 19th century more money could be made wrangling meteorites than cattle, and local ranchers began complaining about a shortage of ranch hands. At the local railroad station, the freight platform was piled high with meteorites.

They were fragments of a 300,000-ton meteorite that originated in the asteroid belt, which lies between the orbits of Mars and Jupiter. Some 49,000 years earlier the meteorite had slammed into the Colorado Plateau, releasing nearly a thousand times more energy than the Hiroshima atomic bomb. The impact left an enormous crater 600 feet deep and nearly a mile wide.

Since it was first documented in 1871, the crater has been called Franklin Hole, Coon Butte, Crater Mound, and Barringer Meteorite Crater, but it's most commonly known as Meteor Crater. Designated a natural landmark by the Department of Interior, the crater has been a tourist attraction since admission was first charged nearly 50 years ago. On Interstate 40 the billboards between Flagstaff and Winslow advertise Navajo rugs, Indian jewelry, and "This planet's most penetrating natural attraction." Each year nearly a quarter of a million visitors follow the signs to visit the crater's museum of astrogeology or hike the three miles around the crater rim.

From the interstate the crater's rim resembles a small butte. Herds of cattle from the neighboring Bar-T-Bar Ranch graze on its slopes among huge boulders. As the road winds toward the crater, the dark reddish brown Moenkopi sandstone changes to the pale gray Kaibab limestone that the meteorite ejected when it struck.

Meteor Crater is now acknowledged as the first topographical feature to be recognized as an impact crater, but a variety of other explanations have been offered to account for its origin. According to a Hopi legend, a Great Spirit made a fiery descent from the heavens into the desert. In 1891, G.K. Gilbert, the chief geologist for the U.S. Geological Survey, came to look for a "buried star" but left thinking the crater was the result of a volcanic steam explosion. However, Daniel Moreau Barringer, a Philadelphia lawyer and mining engineer, believed that a meteorite was responsible for the crater and in 1902 filed a mining claim in the hope of making a fortune from iron-nickel buried in the crater. Theodore Roosevelt signed the patent "in the days when presidents had time to sign mining patents," says the prospector's son, J. Paul Barringer, now 89.

Barringer persevered in his quest for the meteorite until he died in 1929. But his search was mostly in vain: scientists later calculated that 80 percent of the rock had been vaporized, five percent was stripped away by atmospheric friction, five percent was blasted out in a five-mile area surrounding the crater, and only 10 percent was left buried beneath the south portion of the crater's rim.

The Barringer family still owns the crater. In the late 1950s they hired architect Philip Johnson to design the red brick building that perches on the northwest rim and includes the museum and giftshop. The museum displays meteorites (the biggest weighs 1,406 pounds) and related exhibits about planetary science, but it's the vista from the windy observation decks outside the museum that best captures the crater's magnitude.

"There's a lot of color out there in the spring," says site manager Brad Andes, referring to the wildflowers that blossom among the saltbush, snakeweed, and other high desert vegetation in the crater. Mexican eagles and red-tailed hawks can be seen riding the air currents below the decks. Andes says he sometimes encounters coyotes on the trail in the early morning, but the most common wildlife are snakes. "We encourage people to watch where they are putting their feet and their hands," he says.

The observation decks also offer a view of Barringer's labor. All five of his mining shafts are visible, including one that has recently been renovated by the U.S. Geological Survey for sampling the dry lakebeds in the middle of the crater. Amid the juniper on the crater's southeast slope is a mule-powered winch that looks perfectly serviceable. Also still partly intact is an old wooden slide that was used for lowering mining equipment into the crater. "It beat packing everything on the mule," says Andes.

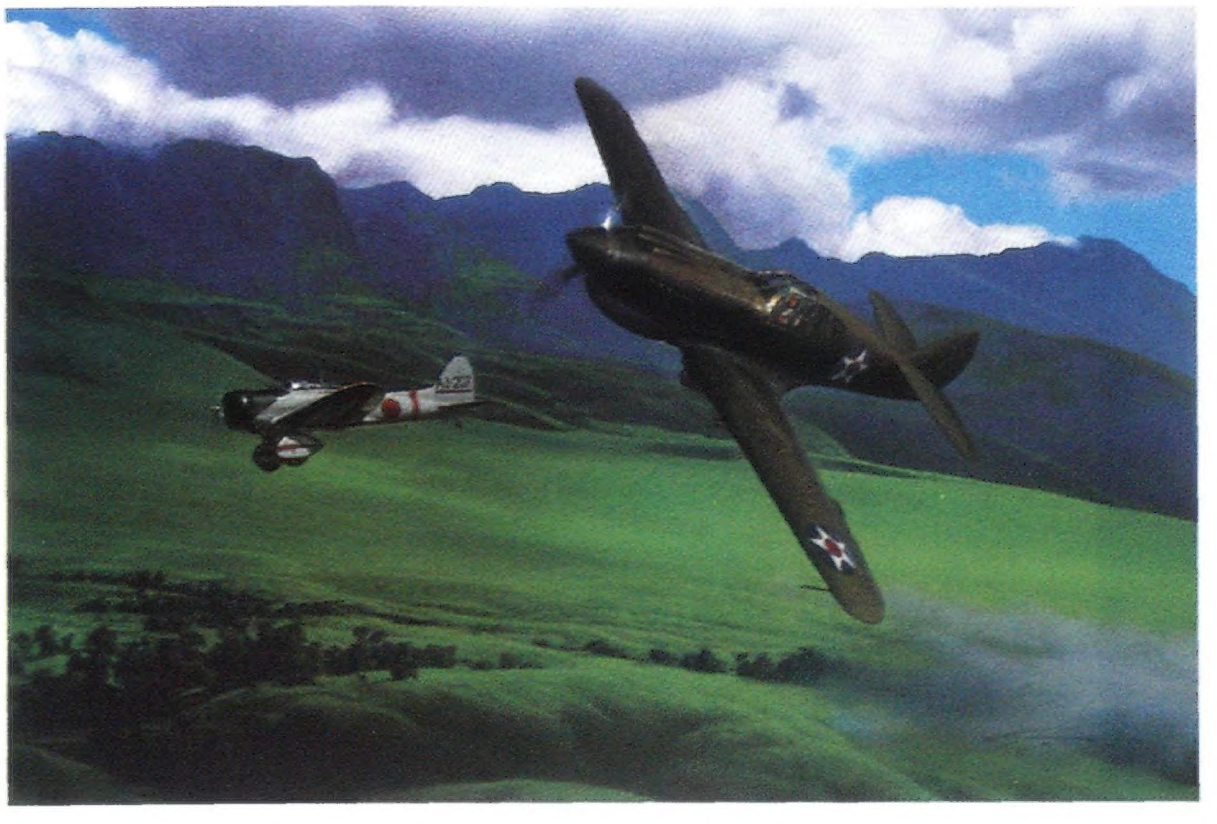
The mules that did make the trip into the crater traveled on a trail that is still visible today. On the opposite side of the crater is another path, known as the Astronaut Trail, which the Apollo astronauts used while training for their exploration of the craters on the moon. A photograph in the museum shows several astronauts wearing Stetsons and gazing into the crater. Real space cowboys.

The astronauts received their geological training from Eugene Shoemaker of the U.S. Geological Survey. In some ways the scientific heir to Daniel Moreau Barringer, Shoemaker has specialized in the geology of Meteor Crater and other impact craters. "That's why we're here in Flagstaff," he says, referring to the astrogeology branch he founded at the USGS. Shoemaker now divides his time between searching for other astronomical bodies on a collision course with earth (see "This Target Earth," October/November 1991) and working at Meteor Crater.

Since Barringer identified this impact crater, over 120 others have been found around the world. "He deserves to be recognized as a pioneer in this whole business," says Shoemaker. In 1972 the Philadelphia mining engineer was honored with a rare tribute: on the far side of the moon is a crater named for Daniel Moreau Barringer.

—David Savold

Meteor Crater is located 35 miles east of Flagstaff, Arizona, on Interstate 40. Phone (602) 526-5259. Open daily; hours vary by season. Admission: $6, discounts for children, students, and seniors.



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(Center) TOO LITTLE, TOO LATE by Keith Ferris, commemorating the Dec. 8, 1941 surprise attack on Clark Field in the Phillipines. Only 1000 Signed and Consecutively Numbered. Countersigned by LT General USAF (Ret.) Joseph Moore, Colonel USAF (Ret.) Sam Grashio, and LT (jg) of the Imperial Japanese Navy Saburo Sakai. Accompanied by the complementary Pacific Theater VHS Living Canvas™ Video. 31½"w x 25⅜"h $245 U.S.

(Bottom) THIS IS NO DRILL by Craig Kodera, honoring the U.S. pilots who got airbourne during the attack on Pearl Harbor. Only 1000 Signed and Consecutively Numbered. Countersigned by Brigadier General USAF (Ret.) Kenneth Taylor, the pilot pictured, and Zenji Abe, a Lieutenant Commander of the Imperial Japanese Navy, who took part in the raid. Accompanied by the complementary Pacific Theater VHS Living Canvas™ Video. 24¾"w x 18¾"h $225 U.S.

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